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This is a quarterly publication presenting articles covering recent developments in Far Eastern (particularly Japanese) scientific research. It is hoped that these reports (which do not constitute part of the scientific literature) will prove to be of value to scientists by providing items of interest well in advance of the usual scientific publications. The articles are written primarily by members of the staff of ONR Tokyo.

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Astronomy
Solar physics
Engineering in India
Fujitsu, Ltd.
Semiconductor devices
Marine sciences in China
Oceanographic data
Coastal data
Fisheries data
Rare earths
Permanent magnets
Samarium
Cobalt
Heterojunction transistors
Molecular beam epitaxy
Titanium
Titanium alloys
Aerospace materials
Deep-submergence vehicles
Corrosion-resistant materials
Turbines
Condensers
Superconductivity

20. Abstract (Cont.)

with certain reports also being contributed by visiting stateside scientists. Occasionally a regional scientist will be invited to submit an article covering his own work, considered to be of special interest.

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George R. Yoder is currently a Metallurgist at the Naval Research Laboratory, where formerly he was an NRC Post-doctoral Resident Research Associate (1970-72) Dr. Yoder received the Ph.D degree from Syracuse University in 1970 Since then, he has published many papers on various facets of the mechanical behavior of materials, including the metallurgical optimization of alloy crack tolerance properties, elastic-plastic fracture analysis, electron fractography of the micromechanisms of fracture and subcritical crack growth, and superplastic deformation His most recent research achievements have been in the area of fatigue crack propagation of titanium alloys. Dr. Yoder has been honored with the prestigious NRL Research Publications Awards for scientific papers in 1973, 1976, 1978, and 1979. He is a member of TMS-AIME, ASTM, ASME, ASM, Sigma Xi and Phi Lambda Upsilon.

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Cover Chinese transporting fertilizer on the Pearl River Delta Reproduced from a photograph by H J Walker of Louisiana State University

SOME CHINESE OCEANOGRAPHY INSTITUTIONS

James Churgin

In November, 1979, four of us (George Saxton, NOAA, Michael Loughridge, NOAA, Frank Wang, USGS, and I) spent three weeks in China, visiting various oceanographic institutions.

HISTORY OF MARINE PROGRAMS IN CHINA

In order to understand the state of marine sciences in China today, we were given a brief history of marine programs since 1949. This history is divided into three periods The first period from 1949 until the mid 50s might be characterized by a number of diverse programs in connection with fishery research, biological oceanography and some physical/chemistry measurements. Data were not collected in a systematic manner and quality was extremely variable Techniques and programs began to improve as experience was gained.

The second period lasted from the mid-50s through the early 60s. This was the time the Chinese refer to as the "Great Leap Forward." It included a 12-year Plan for Ocean Science Research Beginning in 1956, with single-ship investigations of variability in the shallow seas surrounding China, this work grew to multi-ship, regular (four per year) observational stations in 1957-58. With experience, the techniques and quality of observations improved In 1958, a massive 30-ship, 16-institution survey was launched This multidisciplinary survey included the Yellow Sea, East China Sea, South China Sea and Po Hai Bay. As a result of this effort the following data were collected 12,000 ocean stations (T, S, nutrient chemistry), 10,000 stations of current observations (1/hr for 24 hrs.), 10,000 biological and geological samples, 92,000 investigation data sheets, 30,000 tables and charts During the three years following this observational program, the data were processed analyzed and compiled into an atlas containing information on physics (water mass structure and circulation), plankton, nutrients, bottom sediments, bathymetry, etc. These atlas volumes will be made available from EDIS through NODC, ESIC, and NGSDC. This experiment also enabled the PRC to train a cadre of people knowledgeable in the collection, processing, and analyses of oceanographic data.

The third period of oceanographic development began in the mid-60s and continues to the present It includes the period of the cultural revolution in China, when virtually all investigations were suspended and when almost all progress in science and almost everything else came to a halt. In the marine sciences this period may be characterized by single ship area surveys, expansion of coastal stations, the beginning of time-series observations at specific locations, and studies of marine meteorology particularly on the cause, effect, and prediction of storm surges

The coastal station network operated by NBO (see below) now has 51 stations collecting tides, tidal currents, temperature, salinity, and surface weather on a regular basis Daily summary sheets are sent by mail It is planned to submit these by teletype to Beijing in the future Fifty two thousand station/months of data have been collected and are stored at several locations including the Center in Tianjin This Center also receives similar data from coastal stations operated by the Ministries of Aquatic Products, Transportation and the Navy.

NBO also indicated that future plans included more investigations in deep ocean areas of the Pacific and Indian Oceans They did participate in the FGGE program in the western equatorial Pacific and would like to continue this sort of association with international oceanographic programs

My personal conclusion regarding the state-of the-art in marine sciences is that the marine science community has, for the past three years, been very busy obtaining and reading as many papers and publications as possible in order to gain an understanding of modern scientific concepts and technology They have some older scientists trained at western institutions such as Scripps, some trained at Soviet universities, some trained within the PRC, and a generation of people who received some training but have little experience because of the cultural revolution

The Data Center (see below) is reminiscent of the U S NODC in the early 60s. Much of the work is done manually. The computer is equivalent to a second-generation machine with punch tape rather than magnetic tape and most of the output is in the form of printouts of data There is an automated plot capability, although few, if any, data products (summaries, graphics, contours, etc) are created. The computer staff seems to be rather provincial and does not appear to have been exposed to the latest concepts of software design such as structured programming Most of the historical data are not available in automated form and are furnished to requesters as photocopies. The site visit description given below provides additional information on specific activities

The Chinese are extremely eager to "catch-up" both personally and as a matter of government policy. Most of the individual scientists we met appeared to be bright and eager to learn The cultural revolution not only caused a set back in technology development but, because foreign languages, especially English, were forbidden, caused a communication gap which makes discussion at a detailed technical level difficult and slow There is a major effort underway to overcome this problem, but it will take time.

NATIONAL BUREAU OF OCEANOGRAPHY (NBO)

NBO was established in 1964-65 NBO is responsible for programs in all disciplines of oceanography. They are organized into three sub bureaus (South China, East China, and North China or Yellow Sea), three research institutes (First, Second, and Third Institutes), an Institute for Information, and an Institute for Environmental Protection. As far as I could tell, all eight organizations are roughly equivalent in the organization hierarchy. In addition, NBO has a "General Station for Prediction" in Beijing, but I am not sure where this group fits in the organizational picture.

The sub bureaus and institutes have regular observational programs at sea, coastal stations, and a number of research projects There are also special programs such as an East China Sea Shelf Study, prediction research, current measurements network and environmental protection studies in coastal areas which have been completed or started.

The Institute of Marine Scientific and Technological Information consists of a Chart Making Service, Information Research Division, Scientific and Technological Division, Printing House, and Data Collecting and Processing Division. The latter is roughly equivalent to their National Oceanographic Data Center, and I will refer to this Division as the PRC Data Center in this report

SITE VISIT DESCRIPTION

South China Sea Institute of Oceanology, Academia Sinica, Guangzhou (Canton)
Director Qiu Bing-Jing
Vice Director Huang Yun-yae

The South China Sea Institute of Oceanology of the Chinese Academy of Sciences was established in February 1959 The research orientation of Institute emphasizes comprehensive investigations of seas and oceans as well as basic research At the same time, studies on coastal geology and geomorphology, experimental ecology, protection of the environment, sea-air interaction, as well as application of new techniques are also carried on Eight laboratories and an informal research division have been established. The eight laboratories are physical oceanography and meteorology, marine physics, marine chemistry, marine biology, new technology, tectonics, marine sedimentation, coastal and estuarine processes Besides, there are three experimental stations two are in the cities of Zhanjiang and Shantou, respectively, the third is being built in Hainan Island At the present time the total number of the scientific staff amounts to 360.

The Institute has a research vessel, named "Experiment" and two others being built of interest are

- Quaternary geology and neo tectonic movement along the coastal line of South China,
- Physical oceanography in the inshore regions of Guangzhou Province and Peibu Gulf,
- Physical oceanographic structure and return silting in specific bays and harbors,
- Topographic survey and surface sediments investigation in portions of continental shelf waters of the northern South China Sea,
- Study on rearing of pearl oysters and spats,
- Development and evolution of coral reef and mangrove seashore
- Species and ecology of reef building coral in shallow waters,
- Development of marine optical instruments etc

At the present time, the principal contents of research work include

- Marine geophysics and geotectonics,
- Submarine geology and mineral resources;
- Geology and geomorphology of coasts and estuaries,
- Geology and geomorphology of coral reef islands,
- Submarine morphology,
- Structure of sea water masses and currents;
- Sea wave spectra and application;
- Sea-air conditions inducing typhoons in South China Sea,
- Biology and the ecological characteristics of coral reefs,
- Species of marine zooplankton and phytoplankton and the rules of variation of their distribution,
- Experiments on cultivating economic marine animals and plants (mainly, pearl oysters and larvae),
- Neutralization and elimination of harmful organisms and studies on their attachment mechanism (mainly barnacle),
- Investigations on the resources of medical marine organisms;
- Estimation of pollution state and environmental quality in estuarine and coastal waters;
- Rules of distribution and variation of major marine chemical elements;
- Studies concerned with the application of new marine techniques (mainly oceanographic and meteorological auto-observatory buoys as well as submarine laser ranging image-forming device, etc.

In order to meet national goals, some new research activities will begin later, e g , the application of remote sensing techniques in marine investigations, the study on marine erosional environments and mechanisms, a study on marine productivity, etc.

As is the case with almost every "Information and Data Division" we visited, the primary emphasis in the Information Research Division is the collection of hard copy material into a library system. Also in every case great efforts are being made to obtain English language papers, journals, publications, etc and translate them into Chinese

Second Institute of Oceanography, National Bureau of Oceanography Hangzhou
Director· Chang Tsun-bav
Secretary of the Institute· Sung Yih-tsu

The institute was established in March, 1966 It is located in Hangzhou There are about 520 research personnel

The institute is a comprehensive institute of oceanography The main research objective is the natural environment of the East China Sea and its adjacent areas. The principal tasks are to investigate and study the characteristics of the natural environment, marine resources, coastal zone, and the application of aerial remote sensing techniques in marine science. They also have studies on marine environmental forecasting, sea water desalination techniques, and basic marine theories

At present, there are

- Department of Marine Geology, investigate marine sedimentation, sea floor geological formation, structure of the oceanic crust and the distribution of marine gravitational and magnetic fields Depositional mechanisms and sea floor variability are also studied
- Department of Coastal Zone, investigate and study the coast and estuaries and the causes and effects of natural evolution under dynamic actions
- Department of Marine Hydrology and Meteorology, study marine hydrophysical phenomena, atmospheric phenomena and circulation of sea water, as well as the theories for forecasting the marine hydrological and meteorological parameters
- Department of Marine Remote Sensing Techniques, study the spectral characteristics, the methods and the information interpretation techniques of remote sensing on marine environmental parameters
- Department of Marine Chemistry, study the distribution, transformation, and transport of marine chemical elements
- Department of Marine Biology, investigate and study species composition, regional distribution, quantitative variations, and physiological and biochemical characteristics and their variability as related to marine environmental parameters

– Department of Desalination, study the methods of sea water desalination, basic theories and application techniques

Department of Information and Data, scientific information collection, data storage and data services are undertaken in this department.

Besides the above mentioned departments, they are going to establish a department of marine geophysics and a department of comprehensive techniques.

The management of all the scientific research programs and coordination with other institutes is performed by the Scientific Research Division

In touring this facility we noted that they had recently purchased some new equipment from the U S. for determining atomic absorption spectra as well as other laboratory instruments. After our lecture we had a round table discussion with some department heads and scientists. Most of the questions dealt with marine geology and geophysics.

Again, the 30 people in the Information and Data Department are primarily involved in library collecting and translation. Data processing and storage consists of copying and archiving data. Most of what we would consider data processing is done in the research departments.

Although all NBO Research Institutes are comprehensive, i e , include all disciplines, the Second Institute, seems to be particularly interested in marine geology and geophysics

Third Institute of Oceanography, National Bureau of Oceanography, Xiamen (Amoy)
Vice Director Li Changheng

The predecessor of the Institute was the East China Institute of Oceanography of Adacemia Sinica, built in 1959 In 1965 the facility was transferred to NBO. The organization has over 200 professional staff members and occupies 60,000 square meters of space It is organized into six laboratories and a Division of Information and Data. The laboratories are as follows.

- Marine Biology, concentrating on ecological studies of plankton, benthos, and fouling organisms.
- Marine Chemistry; microanalysis of chemical constituents of sea water.
- Marine Geology; sedimentation studies in offshore area.
- Marine Radioisotopes, concentration and excretion of radioisotopes in marine organisms
- Marine Instruments; developed detectors on currents, ultrasonic velocity, and mercury.
- Hydro-meteorology, observation and analysis of currents, waves, and storm surge in Taiwan Straits.

  Division of Information and Data, collecting, processing and dissemination of information, data and library materials Data are all in hardcopy form as far as I could tell, no automated processing occurs in this Division Their current collection contains about 25,000 documents. There are three groups in the division. One is for acquisition of documents, one is for editing and translation, and one for dissemination.

The Institute seems to concentrate on marine biology and chemistry Because this is an area which has not been visited by Westerners, they seem especially anxious to receive publications and other documents dealing with marine scientific subjects.

Xiamen General Ocean Station, National Bureau of Oceanography Xiamen (Amoy)
Director Yu Dexing

This station is one of three such stations under the NBO sub-bureau for the East China Sea Apparently each of the sub bureaus (South China Sea, East China Sea, and North China (Yellow Sea) operates three "Stations." These stations are responsible for the operational (or routine) acquisition, analysis, and dissemination of marine data and information Operational responsibilities include responsibilities for maintenance of ships, buoys, and coastal facilities.

The station we visited was located on the Island of Kulangsu, near the city of Xiamen. It operates nine coastal stations Five of these are on land and are primarily for the collection of sea level data The other four are offshore buoys and collect similar data as well as recordings of wave height from wave staff The station is also responsible for the operation of three research vessels

We also visited one of the coastal stations on Kulangsu Island At this facility, tidal heights are measured continuously. Measurements of tidal current, temperature, salinity, and surface meteorology are also recorded, and daily summaries are forwarded to the Central Station. The Central Station will furnish these, in turn, to both the East China Sea sub-bureau and the Data Center

Geophysical Survey Vessel, HAIYANG I
Captain: Han Qigong
Computation Technology Lin Zhonghe
Chief Office of Marine Geology Shanghai-Wang Shigui

This vessel, which was built in 1972, was recently converted from a general purpose oceanographic research vessel to a geophysical research ship because of China's strong emphasis on offshore surveys for petroleum development. The ship is 105 meters in length, twin screw, 9,000 h.p., maximum speed of 20 knots, and a crew of 61 Scientific survey equipment includes seismic gear manufactured in Texas (DFS #5), Magnavox satellite navigator (MX1107), a gravimeter manufactured in the Federal Republic of Germany (SS #5), and a magnetometer produced in China All equipment is new and a U.S technician was on board testing the seismic instrumentation.

The ship conducts regional reconnaissance along rather widely spaced track lines. All original records are stored at the Office of Marine Geology in Shanghai.

Shanghai Institute of Computation Technology, Shanghai
Department Chiefs: Qian He
Xia Fuxim
Guo Shudong

This is a research organization under the Provincial Government of Shanghai. The staff we spoke with seem to be well aware of the latest developments in computer technology, although virtually all the hardware and software have been developed by the Institute. Research includes not only basic design of computer hardware and software, but also applications which can then be put into operational use by other groups

We were shown several computers. Their most heavily used appeared to be the SJT-731, built in January 1973. The machine has 64K (6 byte) words, core memory, one multiplexor channel with eight selector channels, five magnetic tape drives, a line printer and X-Y plotters on-line. The operating system, as well as ALGOL and COBOL compilers, were developed by this institute. The operating system allows both time-sharing and batch processing as well as multiprogramming.

They are also linked to a university in Shanghai with another computer (SJT-761) and have been able to establish computer-to-computer links using rather low speed line (200 bps).

Applications work includes some oceanographic calculations such as tidal predictions for harbor construction, geostrophic currents, and a two-dimensional model of an estuary.

Shanghai Normal (Teachers) University
Deputy Director: Zhu Shuzheng
Director, Coastal Department: Wan Brochan
Director, Estuary Department Shen Huantung
Director, Topography Department Pan Mingyou

In addition to being a teaching facility, the University also includes a number of research laboratories Some of them are concerned with estuarine, coastal, and oceanic processes. Much of this work is being performed at the mouth of the Yangtze and in associated estuaries. Some 20 years of data have been collected Because of the extremely large tidal range in this area, much of the work is devoted to the effects of tidal processes on port and harbor development, on potential effects of channel dredging, and on sedimentation processes Historical data are used to study the influence of river changes on shoreline development. Also being studied by researchers are ocean hydrology, mineralogy of sediments, geomorphology, and storm surge effects Some new studies include the application of remote sensing to sedimentation studies, carbon determination, and spore analyses Mapping of the Yangtze Estuary and Delta bottom topography has begun From rough sheets at a scale of 1 50,000, a composite bottom topography chart at 1 200,000 is scheduled for completion by 1982.

If this university is typical of others in China, they may also be a good source of data and information, particularly in coastal and estuarine areas.

Qingdao Institute of Oceanology, Academia Sinica, Qingdao (Tsingtao)
Director: Dr. Tsing

This Institute is the largest oceanographic research institute under the Academy It has been visited by a number of Western scientists in recent years and its Director is a graduate of the Scripps Institution of Oceanography. The Institute was founded in 1950 as a marine biological laboratory, adding physics and chemistry in 1952-53 and geology in 1956. In 1959, it received its current designation. This organization has a scientific and technical staff of 530 located in nine departments. Four of these departments are devoted to marine biological research, botany, invertebrate zoology, vertebrate zoology and experimental zoology (mariculture). Four departments are concerned with physics, chemistry, geology and geophysics, and instrumentation. Finally, there is a department of information.

The principal work being conducted here is the area of the China Seas, nearby oceanic areas and the Kuroshio. Studies of marine plants and animals, geology of the continental shelf and marginal seas, shoreline dynamics, principles of mariculture methodology, marine pollution, circulation, tides waves, marine meteorology, harbor models optics and acoustics are all being conducted The Institute publishes one or two journals of their own and contributes to other Chinese scientific journals Samples of their publications were received Most of the data collected as a result of this research either remain in the hands of the researcher or is stored by the Information Department.

A computer is not currently available, but we were told that they are getting a computer associated with a seismic digital data system They also informed us that they were constructing a research ship which will have five shipboard computers.

The First Institute of Oceanography, National Bureau of Oceanography, Qingdao (Tsingtao), Shandong Province
Deputy Director: Wang Yizhen

Th Institute is a comprehensive oceanographic institute under the National Bureau of Oceanography. Its main task is to investigate the natural environment of the Yellow Sea, the Pohai Sea, and its neighboring ocean areas. The Institute conducts investigations of the marine environment and emphasizes applied research. It provides the Bureau and other organizations with data, charts, methods of forecasting and practical technologies to help with their understanding, development, and exploitation of the sea.

Established at the end of 1964, there are more than 200 research workers in the Institute. The Institute consists of four divisions, marine hydro meteorology, marine geology marine biochemistry, and the marine physics. There is also a marine book data service

The task of the marine hydro meteorology division is to investigate waves, currents, salinity, temperature and tides of the seas mentioned above.

The task of the marine geology division is to investigate the coastal zones, ports, and bays, the geomorphology and the history of the evolution and development of the East China Sea

The marine biochemistry division has for its main task research on the methods of determining the pollution of the sea for the purpose of environmental protection It is also performing research on the bionomics of micro-organisms

The marine physics division centers its attention chiefly on marine optics and the application of remote sensing technology in marine science Some of the tasks of the Institute are part of the national plan for the development of science and technology, while others are carried out at the request of local or organizations undertaking offshore development

Yellow Sea Fisheries Research Institute, Bureau of Aquatic Products (Fisheries), Qingdao (Tsingtao), Shandong Province
Deputy Director Xia Shi-fu

This institute was founded in 1946 and has a scientific and technical staff of 150 plus seven research fellows and 48 assistant research fellows. This organization is primarily involved in research for the Yellow Sea and Po Hai Bay, but similar groups exist for the South China Sea and East China Sea.

There are seven laboratories at this institute:

- Marine Resources; studies the distribution and migration of yellow croaker, spanish mackerel, prawns and other commercial species; ecological studies of the effects of hydrocarbons and other pollutants, develop fish forecasting techniques utilizing environmental conditions such as temperature and salinity. In order to develop fish forecasting, temperature/salinity data have been collected for up to ten years at a network of stations. These stations are sampled monthly throughout the fishing season at five meter intervals in shallow areas and 10-to-20-meter intervals in deeper water. The data are then punched onto tape and are fed into a forecast model. I believe these data are made available to the Data Center in Tianjin but it is not clear whether they are on punched tape or on data sheets.
- Fishing Technology; experiments in fish gear technology, acoustic detection, etc.
- Seaweed; studies of culturing techniques for *Laminaria* and *Porphyra*; recently introduced kelp culturing.
- Animal culturing; aquaculture techniques for sea cucumbers, prawns, oysters, mussels and fish are studied.
- Fish processing; methods to protect freshness of fish in canneries.
- Information services; library, data archives and translation services.

Catch statistics and catch per unit of effort are produced manually. The institute is currently experimenting with broadcasts of fish forecasts to vessels. They use a Chinese mechanical bathythermograph which they calibrate and also use a Japanese STD at their hydrographic station. The STD produces both an analog and digital recording. Time and interpretation difficulties did not permit our going into the detail of data reduction techniques, but it was most interesting to note that they are so deeply involved in the relationship of the ocean environment to fishery production.

Research Vessel R/V XIANG YANG HONG No. 9
Head of Commanding Department, East China Sea Sub-Bureau: Cui Bingxin
Captain: Zhang Jing
Chief Scientist: Wang Zhong Shan

This vessel is a general-purpose oceanographic research ship capable of conducting deep ocean, as well as coastal measurements. The ship was launched in 1978 and is 112 meters long, 15 meters wide, with a draft of 5.5 meters. It can work for up to 60 days without resupply and took part in the FGGE equatorial program for a seven-month period in the vicinity of 175° E.

Navigation equipment include a satellite navigator, Loran A and C, and Omega. Oceanographic winches and instrumentation for physical, chemical, biological, and geological work were seen. Both upper air and surface meteorological data were collected during the FGGE experiment. It was my impression that this ship could be used for almost any kind of oceanographic experiment if modern instrumentation (including computers) and trained personnel were available.

Institute of Marine Scientific and Technological Information, National Bureau of Oceanography, Tianjin (Tiesen)
Director: Wang Duo
Deputy Director: Sun Ende
Chief of Scientific and Technological Division: Luo Chuanwei
Director of Information Research Division: Xu Zhemen
Director of the Data Collecting and Processing Division: Hou Wenfeng
Director of the Chart Making Service: Zhang Xishen
Head of Printing House: Zheng Xing-quo

This institute was started in 1964, and in 1965 underwent organizational and functional changes to its present name and mission. It is difficult to find an analogous organization in NOAA as it combines some functions of EDIS and NOS together with minor elements of other NOAA groups. The major divisions are

- Information research, primarily conducts the library, translation, and other information dissemination functions
- Chart making, produces both bathymetric (topographic) and meteorological/oceanographic charts and products.
- Printing house, operates printing plant using what appeared to me to be rather outdated equipment and methods. The labor required to select typeset from thousands of Chinese characters was quite fascinating.
- Data collection and processing, this division performs most of the functions of an NODC and is what I have referred to in this report as the Chinese Data Center. The division has acquired data from foreign countries as well as PRC sources and now has a total of 500,000 physical/chemical stations. All of these are in the originator's format. Some XBT, BT and geophysical data are stored here but in limited quantities. The mission of the division is to acquire, process and disseminate oceanographic data from and to all organizations in the PRC having marine interests.

There are eight groups or branches as follows

- Data information, the mission of this group is to acquire data and provide services to customers. Data acquired are both foreign and domestic. Foreign data are acquired through exchange, NBO data by directive and other PRC organizations through negotiated agreements Data reports in published form may be obtained through a central agency similar to NTIS or DDC.
- Basic data computation group, their mission is to process data and compile them into data reports. Station data, coastal observations, and tidal data are processed. They may also develop technical specifications for compilations. Most of the work is done manually. All pre-1977 tidal stations have been processed. Post 1975 station data have now been placed on punched tape.
- Environmental atlas compilation, the mission of this group is to produce atlases of the China Seas or specified ocean areas. These atlases contain information on currents, waves, sea temperatures, salinity, bathymetry, and geology. In order to prepare atlas material data are statistically compiled into 1°, 2°, 5°, or 10° square averages. Atlases for the North Pacific, South Pacific, North Atlantic, Indian Ocean, Taiwan Straits, and Japan Sea have been completed. The addition of geology, geophysics and bathymetry has recently been started.
- Data services, the mission of this group is the management and dissemination of stored data records. They prepare catalogs and provide data to requesters usually in hardcopy form either from printouts offset printing or photocopying devices. Some data are stored on microfilm or microfiche, although these collections do not seem to be extensive. About 1,000 requests per year are received.

The data base is said to contain the following items:

- 50,000 coastal stations with temperature and salinity values,
- 80,000 ocean stations physical-chemical,
- 4,000 current stations, hourly for 24 hours,
- 4,000 variable depth, current profiles,
- 3,000 time series stations,
- 24,000 ship of opportunity observations (foreign),
- 13,000 ship of opportunity observations (Chinese), standard ocean stations are increasing at the rate of about 3,000 per year and are expected to increase by 10,000 per year in the early 1980's
- Data processing; primarily a tape punching group
- Programming, their mission is the system design, programming and implementation of processing and applications programs They have just completed a systems study of processing and interpolation techniques for station data Their computation routines are very similar to ours They are now studying methods for compressing and uncompressing data.
- Computer maintenance; their mission is to operate and maintain the DGS computer
- Tide and Tidal Current Prediction, this group is responsible for analysis and prediction of tides and tidal currents for the China Seas It also conducts research on prediction methods In addition to compiling tide tables for China, they have recently started to produce world wide tide tables. From time to time they are called upon to provide special analyses for projects such as harbor construction

The Division Director expressed a desire to expand acquisition, improve processing, develop data products, and perform other data management tasks with greater efficiency and accuracy At the present time the data information group is responsible for quality control of data, but they really depend on the originator to decide whether corrections are needed and to provide them

Mr. Luo Chuanwei provided us with an insight as to the NBO plans for upgrading this facility into a fully operational NODC. These plans include expansion of all functional areas, development of standard systems and formats, regionalizations, international exchanges, training in modern computer hardware and software technology, new facilities, and new equipment, including a large mainframe computer.

ELECTRICAL ENGINEERING AT THE INDIAN INSTITUTE OF TECHNOLOGY, DELHI, AND SOME CENTERS OF INDIAN ASTRONOMY

Nelson M. Blachman

The 16 February, 1980, total solar eclipse that traced a path across Africa and Asia provided the impetus of a scientific tour of India sponsored by the American Astronomical Society. The 60 participants in the tour included over a dozen astronomers, along with assorted other scientists. This article summarizes information gathered during the course of the tour and at the Indian Institute of Technology, Delhi, which I had been invited to visit afterward to present some lectures on statistical communication theory.

TATA INSTITUTE OF FUNDAMENTAL RESEARCH

The tour began with the Tata Institute of Fundamental Research (Homi Bhabha Road, Bombay 400005), founded in 1945 and directed now by Dr. B. V. Sreekantan, which is engaged in nuclear physics, genetics, astronomy, chemistry, solid-state physics, and computer software research. This institute also awards Ph.D.'s in physics and mathematics, having had 70 and 35 candidates enrolled in these two fields, respectively, at the time. Lecture courses fill the first two years of these student's studies.

Among the TIFR astronomical projects underway is a 1000-kg telescope, 5½ meters in height, with a 75-cm aperture and three-axis mounting, which is to be carried to an altitude of 30 km by balloon. The TIFR has a command and telemetering station in Hyderabad that will be used in connection with this telescope for 20-micron infrared studies. Another project involves a 55 kg balloon-borne array of four cosmic-ray detectors, also to be launched from Hyderabad to a 3-millibar altitude (25 miles) and recovered, for the counting and spectral analysis of 20-to-100-kV x rays with a 6° x 6° acceptance angle. The four detectors fill a 1-m cube.

TIFR is building equipment to be put aboard the first Space-Shuttle Spacelab in coordination with NASA to determine the abundances and energies of the heavy ions in 5-to-100-MeV/nucleon cosmic rays and their times and directions of arrival. It is hoped that recorded and telemetered measurements will indicate the origin of the anomalous distribution of elements between carbon and iron in the low-energy cosmic rays The equipment is scheduled for completion in 1981 in a 30-kg cylinder of 48-cm diameter and 53-cm height. It is to be returned to earth in April 1982, after a week in orbit Professor S. Biswas of TIFR is heading the Indian participation in the NASA mission, which includes contribution from the Physical Research Laboratory in Ahmedabad and assistance from other Indian organizations.

In 1959, TIFR built India's first indigenous digital computer, the TIFRAC, patterned after the ORDVAC. In 1960, TIFR built a second digital computer – this one patterned after the ILLIAC, and in 1967 a third one Meanwhile, in 1964 a centralized CDC 3600 was purchased from the U.S. which is used by some 75 organizations in India, TIFR among them. In addition, TIFR has a new machine, the OLDAP – constructed from Indian components originally intended for the entertainment industry – which is tied to their bubble chamber and is functioning successfully, as well as such other U.S. minicomputers, such as a PDP-8 and a PDP-11.

In 1975, the Indian Atomic Energy Commission decided to establish a national computation center along with regional centers Thus, a design center is being set up in Bangalore, an information center in Delhi, and a software division and regional center in Bombay. The plan is proceeding well with the help of UN financing, and work on graphics for mechanical design is underway. A satellite network of small machines is also being developed TIFR is devising a phonetic alphabet suitable for this system's handling all of the 14 official languages of the country India's problems in this regard dwarf those of Canada, Belgium, and Switzerland, as the Dravidian languages of the South belong to an entirely different family from the Sanskritic (Indo-European) languages of the North.

THE TOTAL ECLIPSE

The eclipse's zone of totality crossed India south of Hyderabad and included the astronomical observatory between the towns of Japal and Rangapur, to which NSF sent teams and equipment from a dozen U.S universities and observatories. The AAS tour visited the Japal-Rangapur Observatory on the day before the eclipse so as to avoid interfering with the measurements. These were directed not at observation of any new phenomena but, rather at more detailed and more precise recording and measurement of such things as the green iron line in the corona, 5 solar radii from the center of the disk (photographed by means of a Fabry-Perot etalon), and the 3-micron radiation at 20 solar radii (viewed by a spirally scanning radiometer). A heliostat was being used to provide several images whose Doppler shifts were to be compared in order to determine the speed of coronal motion with a resolution better than 0.5 km/s.

With 30-Hz digital sampling, 1-s oscillations (Alfven waves) in coronal loops with an amplitude of a few percent were to be studied, telex communications from the U.S. and from Africa were to point out where to find the loops. At that site, the totality lasted 130 s, while at the village of Palem, 80 km south of Hyderabad, from which the AAS tour observed the eclipse very close to the center of the path of totality, its duration was 150 s. Because of the proximity of the moon to the earth at that time, the width of the path of totality was 75 miles, and the twilight seen all around the horizon during the eclipse was therefore scattered from some forty miles away in all directions.

Viewing conditions were perfect in Palem, but most Indians remained indoors during the eclipse with the shades drawn to avoid any untoward effects, and a number of Indian states declared the day a holiday. During the semidarkness at 3·45 p.m. Indian time (Greenwich + 5½), birds went to roost, and mosquitoes began to bite.

INDIAN INSTITUTE OF ASTROPHYSICS

Continuing south, the AAS tour next visited the Indian Institute of Astrophysics (Bangalore 560034), founded in Madras in 1792, whose director, M. K. Vainu Bappu, currently president of the International Astronomical Union, had received his Ph.D. at Harvard University in 1952. In Bangalore, the IIA headquarters has a library, optical shop, and future mechanical shop; 60 km to the north in Gauri Bidanu (13° 36′ N) is an IIA astronomical field station operated jointly with the Raman Research Institute, which has a 30-MHz radio telescope a T-shaped lineer array of dipoles with a 30,000-m^2 collecting area and resolutions of 20′ E-W and 40′ N-S, the respective arms being 1.6 km and 0.5 km long. At Kavalur (12° 34′ N), where the IIA has been active since 1892, it has a 40-inch Zeiss Ritchey-Chretien reflecting telescope capable of f/6.5 direct photography and equipped with an f/2 Meinel camera, f/13 scanning spectrograph, and f/30 coude spectrograph providing dispersions from 2 Å/mm (echelle) to 12.8 Å/mm (grating) Under construction in Kavalur are four additional instruments a 15-inch reflector photographing at f/325, a 93-inch reflector working at f/13 and f/45 (coude focus), a 30-inch reflector, and a 60-inch solar tower.

At Kodaikanal (10° 14′ N) the IIA works in the fields of solar physics and solar-terrestrial physics, it has an ionospheric and magnetic observatory there as well as a variety of optical instruments These include a 12-inch horizontal telescope and a 60-foot spectrograph with a dispersion of 9 mm/Å and a spectral resolution of one part in 600,000, to which a 13-inch solar image is fed by a 15-inch lens

For the eclipse, the IIA formed two teams in case of adverse weather. At their western camp they set up a quadruple polarigraph giving a 10-mm solar diameter, and including the corona out to 3 solar radii, several coronal spectrographs covering the dispersion range from 26 to 3600 Å/mm with curved slits maximizing angular coverage, which was well over 90°, and white-light photography with a 50-mm solar diameter Their eastern camp utilized monochromatic photography covering the green, red, and yellow lines. The spicule structure was studied via a 50-mm image with 2 Å/mm dispersion provided by a transmission grating. As it turned out, both camps had fine weather.

RAMAN RESEARCH INSTITUTE

The last scientific organization visited on the AAS tour was the *Raman Research Institute* (Bangalore 560 006), with a staff of forty scientists now directed by Dr V. Radhakrishnan The RRI was founded in 1948 (when India had gained independence from Britain) by Sir Chadrasekara Venkata Raman (1888-1970) with the funds from the Nobel prize he had received in 1930 for his work on the scattering of light and the discovery of the effect now known by his name The institute was originally devoted to the study of physics in general, but it is at present concerned principally with milli metric radioastronomy The RRI's radiotelescope, with antenna of 10-m diameter, is to be completed in 1981 and is to operate down to a wavelength of 1 5 mm with a hoped-for 2-arc-second resolution. It will have a cooled preamplifier at the cassegrain focus Also, a 1 5-m radiotelescope with a coude focus and millimetric waveguide will be installed in the dome of the institute's building, which has so far remained empty The institute has already been using the 28-to-38 MHz T-shaped linear array of dipoles in Gauri Bidanur mentioned above to map the galaxy at long wave-lengths and locate the ionized hydrogen as well as to observe the solar radiation and planetary emissions More generally, the work of the RRI covers general relativity, including the physics of black holes, gravitational radiation, the propagation of neutrinos in strong gravitational fields (e g., near black holes), and the exact solution of Einstein's equations; and high-energy astrophysics, including neutron stars, pulsars, supernovae, x-ray sources, and x-ray busters. During the eclipse an RRI team looked unsuccessfully in a 30-km/hr wind for shadow bands of light on the ground paralleling the disappearing and reappearing thin crescent of the solar disk–the occasional result of refraction by atmospheric inhomogeneities. They had laid out an array of photocells with 1-meter spacing along the arms of a T and used analog recording with subsequent Fourier analysis up to 500 Hz.

Astronomy seems to be well supported in India, as the configurations of the heavenly bodies have long been of great importance to both the rulers and the people of the subcontinent. Even today, among many educated people, horoscopes determine the suitability and appropriate dates for marriages. It thus seems that the belief in astrology has not been altogether bad for science.

INDIAN INSTITUTE OF TECHNOLOGY, DELHI

Finally, I visited the Indian Institute of Technology, Delhi 100029–one of the five autonomous campuses of the ITT, the others being in Bombay, Kanpur, Kharagpur, and Madras. Their total student population is about 14,000. The Delhi campus, the youngest and smallest of the five, was established in 1963 as the successor to the College of Engineering and Technology, Delhi, and is located in the village of Hauz Khas on the southeastern edge of New Delhi, on the opposite side from the old city. About half of its 2400 students are working for their first degree, bachelor of technology in chemical, civil, electrical, or mechanical engineering or in textile technology, or master of science in chemistry or physics, all of which are five-year (soon to change to four-year) programs. The advanced degrees, M. Tech. (two-year program of courses and project) and Ph.D., are offered not only in these departments but also in applied mechanics, mathematics, and systems and management studies.

Teaching in all IITs is entirely in English (with occasional local admixtures), although English is not the first language of most of the students, and Hindi serves as a secondary language on the Delhi campus. English is one of the country's official languages, and here it differs from both the British and American dialects.

On the 115 engineering colleges in India, some are supported by the states and others by the national government's University Grants Committee. The IIT's, in contrast, as Institutes of National Importance, are directly under the Ministry of Education, and in total they got nearly as much financial support as all the rest combined. There is a joint entrance examination for the five IIT's, which 40,000 candidates take annually at the age of 16 or 17 after eleven years of schooling, there being nothing in India like Britain's O- and A-level examinations. There are places for only 1300 students, however, 250 of these being in Delhi, with one-fifth in each department, although the greatest demand is in electrical engineering. Thus, the EE Department is able to choose the creme de la creme.

During their final year, undergraduates are required to undertake an individual or group project–usually in collaboration with public or private industry–and on graduating, most students find engineering jobs in various parts of India, but 10-15% go into management, and an equal number go to the U.S. or Canada. Many of these students turn out to be very good, particularly so because Indian schooling at the lower levels is at its best much more advanced than in the U.S. and because of the greater selectivity in India, but others can succeed in graduating with grades no higher than D. For the M.Tech. degree, an average of at least C– is required. Many of the M.Tech. candidates are sponsored by industry or are faculty members from other engineering schools sent for upgrading. In addition, the IIT offers over a dozen short courses during each summer and winter vacation.

The Electrical Engineering Department has 40 faculty members headed by Professor P. S Satsangi, Ph.D., 250 undergraduates, and 80 graduate students–the great majority of them working for the Ph.D., though part-time in some cases. Of the Department's five groups, the largest is Control Systems. The others are Power Apparatus and Systems, Communications, (solid-state) Electronics, and Computers Undergraduates can specialize in any of these areas, and graduate students have the additional choice of communications and radar (including underwater electronics). The

Department also offers a one-year postgraduate diploma course in the last field for students sponsored by defense organizations.

At the IIT there is a heavy emphasis on practical training and collaboration with industry and with government agencies which has resulted in the carrying on of about a hundred consultancy projects each year. In line with this principle, a research and development center called the School of Radar Studies was set up at IIT/Delhi in 1971 by the Communications Project Office of the Ministry of Defence. In its laboratories and offices adjoining those of the EE Department, civil servants, faculty members, and students have collaborated in the field of radar components and systems. More recently the school has evolved into the Centre for Applied Research in Electronics (CARE), and its scope has been broadened to include sonar, missile electronics, digital systems, and work for various government agencies such as Indian Railways as well as for some private industrial enterprises.

CARE's activities fall broadly into three areas of electronics. signal processing, microwaves, and solid-state devices. The latter area includes the design, fabrication, and application of surface-acoustic-wave devices, charge-transfer devices, integrated circuits, and solar cells. In the microwave area, a tropospheric-propagation measurement project is underway over a 160-km path from Delhi to Pilani. An eight-element linear X-band phased array was built originally using imported electronically controlled phase shifters, but now the microwave laboratory is able to fabricate ferrite waveguide and microstrip phase shifters, broadband directional couplers and power dividers, three-octave microstrip-to-microslot transitions, and balanced mixers. Their work on the production of microwave integrated circuits is intended both to provide experience in their use and to permit domestic manufacture of things previously available only from abroad (mainly the U.S.) and only with the expenditure of scarce foreign currency.

In the CARE communication, radar, and sonar laboratory, whose door bears the label "Restricted," I was shown a digital underwater communication system utilizing a 300-Hz bandwidth in the 10-to-15-kHz range. It is being developed to transmit perhaps 8 out of 16 possible frequencies during 200-ms keying interval. In this way it might be able to transmit 65 bits per second. However, a smaller signaling rate, perhaps about 20 b/s, results from the restriction to orthogonal signals.

A digital automatic gain control has been developed for radar signals that achieves a 60-dB compression with a 4-dB step size and a dynamic range exceeding 80 dB; and a pipelined 64-sample fast Fourier transformer with a 1-MHz throughput rate has been built from indigenous components for signal processing, particularly in an application to submarine detection. This detection system is already in operational use by the Indian Navy.

In another CARE laboratory I was shown equipment developed for the counting of railroad cars entering and leaving sections of track. It involves the transmission of an ultrasonic beam across the top of a rail, this beam being blocked by the passage of a wheel. The logic needed in order to make it fail safe is being improved, but a version of the counter already developed at IIT/Delhi is in widespread use by Indian railways with production valued at $1 million per year.

There are, in addition, many other research topics being investigated, and the IIT/Delhi has an ICL 1909 centralized computer system with 32K of core storage and 8K million characters of disk storage, etc., obtained with the help of the UK Ministry of Overseas Development, which is being upgraded by the delivery of an ICL 2960 computer system. Under the Colombo Plan there are also numerous other grants in aid for the purchase of British laboratory equipment, and there are many pieces of American equipment, such as a PDP-8E, HP 9830, and Intelec-8 computers in the Electrical Engineering Department as well as numerous Intel 8080 microprocessors and a Tektronix storage oscilloscope, some of which were obtained with Ford and Rockefeller Foundation support.

Aid from Britain, the U.S., and other countries also permits faculty members to spend sabbaticals and attend conferences abroad, thus helping to alleviate the isolation due to India's great distance from most advanced countries, its scarcity of funds for imported equipment, and the delays of several months in the delivery of technical journals from abroad because air-mail postage is often deemed too dear a luxury Among those in the Electrical Engineering Department who have recently had fellowships in the U S are professor S C. Dutta Roy (1978-9), whose interest is in circuits (including CCD signal processing), Professor J Nanda (1978-9) (control systems), and Assistant Professor B Mathur (1979) (the design of charge-transfer devices) Assistant Professor S C Kak was away at Louisiana State University for an extended period at the time of my visit His interests are in cybernetics, cryptography, and communication theory

Another Department member who has recently spent several years in the U.S. is Dr. Ramesh C. Agarwal, who, after getting his B.Tech. (Hons.) in electrical engineering from IIT/Bombay in 1968, went to Rice University for his advanced degrees in this field (1970 and 1974) with a year's interruption to serve as an associate lecturer at the School of Radar Studies, ITT/Delhi. From 1974 until 1977, he worked at the IBM Yorktown Heights Research Center, then returning to India to join the CARE at IIT/Delhi. He is noted for his work (with C. S. Burrus of Rice University) on "Fast One-Dimensional Convolutions by Multi-dimensional Techniques" (*IEEE* Trans , vol. ASSP-22, pp. 1-10, Feb. 1974) and "Fast Convolution using Fermat Number Transforms with Applications to Digital Filtering" (*ibid.*, pp. 87-97, April 1974) and (with J. W. Cooley of IBM) "New Algorithms for Digital Convolution" (*ibid.*, vol. ASSP-25, pp. 392-410, Oct. 1977), all of which have been reprinted in J. M. McClellan and C. M. Rader (eds.), *Number Theory in Digital Signal Processing* (Prentice-Hall, 1979). His paper (with Burrus) "Number-theoretic Transforms to Implement Fast Digital Convolution" (*Proc. IEEE*, vol. 63, pp. 550-560, April 1975) is also worth noting. He has, in addition, published a number of papers on applications of digital signal processing to the development of computationally efficient algorithms for refining the structures of large biological molecules on the basis of x-ray diffraction data. For his work on number-theoretic transforms he received the IEEE Acoustics, Speech, and Signal Processing Group's senior award in 1974. He and his wife had been very happy in the U.S. and at IBM, where he might have remained, but in the end he decided to return to his native land and to his extended family. Because Agarwal's work is entirely theoretical, it can continue without difficulty in India. Thus, India does not permanently lose all those who go abroad, although many merely make occasional trips back there, which also help to bring India the benefits of work done elsewhere.

On the other hand, India is also sharing its technological knowledge with less advanced countries. My host during the visit, Assistant Professor Suresh N. Gupta, head of the Department's communication group, had spent the preceding academic year as Visiting Reader in the Department of Electrical and Communication Engineering of the Papua New Guinea University of Technology. He had received the B.Sc. (Hons.) degree in physics from the University of Delhi in 1958, the B.E. (distinction), M.E. (Distinction), and Ph.D. in electrical communication engineering from the Indian Institute of Science, Bangalore, in 1961, 1962, and 1968. His doctoral research and most of his subsequent work have dealt with atmospheric radio noise and its effect on digital communication systems.

During my visit I met too many people to permit describing all of them in this report, but it seems worthwhile to mention one more, Professor Rajendra K. Arora, who obtained his Ph.D. from St. Andrews University, Scotland, and whose field is microwave devices, antennas (particularly phased-array antennas), and propagation. He is chairman of the Delhi Section (Western Northern India) of the Institute of Electrical and Electronic Engineers (IEEE, New York) with 350 members. There are four other Indian sections, with headquarters in Bangalore, Bombay, Calcutta, and Madras, the total Indian membership being 1700 when student-members are included.

India is a country of vast diversity, as is illustrated, for example, by the great variety of vehicles that share its roads – from bullock carts and three-wheeled pedaled taxis to the most modern gasoline- and diesel-powered cars and trucks. It has many problems, and it also has great potential. By restricting foreign ownership of manufacturing operations in India to no more than 40%, the government hopes to avoid recolonization But to promote the growth of electronics in India and especially to promote export, it has set aside a 100-acre industrial zone, the Santa Cruz Electronics Export Processing Zone, in Bombay in which 100% foreign ownership is permitted. The Zone is given excise and customs exemptions, low-cost leases with concessions on municipal taxes, and a waiver of licensing requirements for the import of capital goods and production supplies. Furthermore, goods supplied to the Zone from the rest of the country are regarded as exports and thus given preferential treatment and concessions. To date the Zone has attracted 39 foreign manufacturers – including 16 from the U S. – and it expects to add three more soon.

The reduction of red tape in the Zone is helpful in overcoming one of the problems slowing India's progress, and in time it is hoped that similar reductions will take place throughout the country and that ways will be found to lessen the other problems that have so far kept India from joining Japan, Taiwan, Hong Kong, Singapore, and Korea as suppliers of the world's electronics. What I saw at IIT/Delhi suggests that India should ultimately succeed in doing so

ELECTROSTATIC PRECIPITATION RESEARCH AT THE AUSTRALIAN COAL INDUSTRY RESEARCH LABORATORY, LTD.[1]

Leon H. Fisher

INTRODUCTION

The Australian Coal Industry Research Laboratory Ltd. (ACIRL) is a private non-profit organization. Prior to 1965, the organization existed as a wholly owned entity of the Australian black coal industry (Australian Coal Association). It was orginally formed by the coal industry in 1956 as a merger of Coal Research Ltd. and Northern Colliery Pty. Research Laboratories. From 1956 to 1965, ACIRL was supported by levies made against the coal industry. In 1962, the Australian Coal Utilization Research Advisory Committee recommended that the Australian government become interested in supporting coal research and development. As a result, the government decided to allocate money for this purpose on an annual basis and to effect a reorganization of ACIRL to its present status.

ACIRL has a 15-member board of management. The board includes eight members from industry, appointed by the Australian Coal Association, and seven members representing the Australian national government and some of the Australian state governments. The industrial representatives control 51% of the votes on the Board. The non-industrial members of the Board include three from the government of Australia (Department of National Development, Joint Coal Board, and Commonwealth Scientific and Industrial Research Organization), and one each from the governments of South Australia, Queensland, New South Wales, and Victoria.

The primary objects of ACIRL are to be concerned with all aspects of coal mining, beneficiation (economical preparation of coal for users), and utilization of coal and by-products derived from coal. It is the only organization in Australia specializing wholly in coal research. ACIRL keeps in close touch with Electric Power Research Institute (EPRI) of Palo Alto, California, and has reciprocal agreements with that organization. ACIRL has carried out work on resistivity of fly ash under contract for EPRI.

ACIRL is an expanding organization with a staff of 190, 60 of which are professional. ACIRL is not a contract granting organization. It accepts commissions to carry out work for clients on an absolutely confidential basis, and it accepts grants as well for non-confidential research. About 35% of the funds for non-confidential research come from the coal industry and about 65% come from the Australian government through the National Energy Research Development and Demonstration Program. For the year ended June 30, 1979, funds for confidential and for non-confidential research amounted to A$2.1 million and A$1.3 million, respectively, giving a net operating revenue for this period of about A$3.5 million. The commissioned research was carried out for 175 clients with an average amount of about A$12,000 per client. However, there is tremendous dispersion about the mean, some clients having had services performed for as little as a few dollars. For the year ended June 30, 1980, the volume of confidential and non-confidential research were about equal.

ACIRL operates five laboratories as well as two coal preparation stations and one mine model research station. The five laboratories have some types of equipment in common for analytical work, but certain of these laboratories have additional items for specialized work. These installations are now listed with their locations along with some of their specialized equipment and activities:

- Central Laboratory, 22-30 Delhi Road, North Ryde, N. S. W. (also head office of ACIRL, pilot plant facilities, mechanical testing, acoustic and vibration measurements, physical measurements, x-ray fluorescence spectrophotometer, scanning electron microscope for analyzing coal ash, and gas chromatograph-mass spectrometer),
- Southern District Laboratory, York Road, Bellambi, N S. W. (located near the southern coal fields, physics and chemistry for coal analysis),

- Northern District Laboratory, Junction Street, East Greta Junction, Telarah, N. S. W. (close to the N. S. W. northern coal fields, coal analysis);
- West Moreton District Laboratory, Foote Lane, Ipswich, Queensland (standard coal analysis laboratory),
- Central Queensland District Laboratory, Gavial Creek, Wharf Street, Rockhampton, Queensland (standard laboratory for coal analysis, studies of how to reduce mineral content of coal for export, large scale testing, petrographic capabilities, optical examination of polished coal samples),
- Maitland Coal Preparation Station, at the same address as the Northern District Laboratory; and
- Rockhampton Coal Preparation Station, at the same address as the Central Queensland District Laboratory. The Mine Model Research Station is located at the same address as the Southern District Laboratory.

Although I am not a coal scientist, and although the purpose of my visit to ACIRL (Central Laboratory) was to learn about electrostatic precipitation problems of fly ash, I am including a list of problems on which ACIRL is working other than electrostatic precipitation:

- underground mining of thick coal seams,
- prediction of mining conditions from bore core information,
- development of mathematical modelling techniques for evaluating stability of underground mine openings,
- methods of mining the Greta seam at depth.
- prediction, prevention and/or control of outbursts,
- methane drainage,
- roof control,
- prevention and control of spontaneous combustion,
- filtration characteristics of fine coal,
- coal washery reject disposal,
- production of oil and chemicals from coal,
- coal carbonization, and
- combustion and environmental protection research.

Another problem is the precision of measurement of coal reserves. This project is concerned with the variability of each of the coal properties of interest within an exploration prospect. Such knowledge is used to assess the adequacy of the drilling program in different regions of the field, and as an aid in optimizing the design of the preparation plants by estimating the range of raw coal quality.

A final problem is underground mining research in the Collie coalfield, Western Australia. The object of this project is to improve the stability of the overlying strata by reduction of the water content and to design alternative mining methods to permit increased percentage recovery of the coal seam in the Collie coal basin in Western Australia.

It is with Environmental Protection Research that the rest of this report is concerned. However, before proceeding with environmental protection research, a few general comments can be made about the problems of Australian coal. At present, only about 50% of the coal from any one seam is recovered. Problems exist for both thick and thin seams. A reassessment of what constitutes a suitable source of coal in Australia will have to be made as the need for coal becomes more urgent. It is predicted that by the year 2000, Australia will have increased its coal production by about a factor of four and that at that time about two-thirds of Australian coal will be exported for power generation. (At the present time, Australia exports only a small percentage of its coal production.) Thus decisions will have to be made about exploiting coal supplies which are at present located under bridges, gas lines, electric lines, buildings, and dams Sydney sits over coal seams, but if they were to be mined, the water supply might become endangered. Up to now, most mining of coal in Australia has been surface mining, problems associated with mining coal in depth will have to be considered New deposits of coal will have to be evaluated carefully especially with regard to environmental requirements

ELECTROSTATIC PRECIPITATION RESEARCH AT ACIRL

My host at the Central Laboratory of ACIRL was Kenneth M. Sullivan, principal fuel engineer His area of interest is combustion and environmental evaluation and control relating to coal usage He brings a lifetime of practical experience to this work

ACIRL has been involved for many years in the problem of how to ensure that a power station will be properly designed to fire a previously unused coal deposit over the life of the deposit, taking into account the combustion and fouling characteristics of the coal, as well as considering the problem of electrostatic precipitation of the fly ash. ACIRL proposes that the coal field be geologically surveyed and that small core coal samples be obtained from the planned area of operation, covering the life of the power station, and tested in a number of ways. Although chemical and physical analysis of the coal helps to determine the combustion and fouling properties, such procedures have been found to be inadequate for predicting the electrostatic precipitability of the resulting fly ash.

In an attempt to provide an answer to the determination of the proper design of full-scale electrostatic precipitators for fly ash from as yet unexploited coal deposits, ACIRL proposes that "synthetic" fly ash be produced from a small amount of coal (2 to 5 kg) obtained from 50-mm bore cores in a suitably designed laboratory micro-furnace. Such laboratory micro-furnaces have been developed at ACIRL over the past ten years. Testing over a number of years by ACIRL has shown that a suitably designed laboratory furnace produces a fly ash similar to that produced in a full-scale boiler from the same coal. Preferably the cores should be fired as soon as practicable after extraction. They should not be stored in excess of six months prior to firing, otherwise oxidation may affect combustion conditions.

The micro-furnace is heated electrically to produce a fixed temperature profile ranging up to 1450°C along a 38-mm-bore vertical tube 100 cm in length. The coal sample is milled to pulverized fuel consistency, and then fed into the furnace with good dispersion at a constant rate with a mixture of propane, oxygen, and air, so that each coal particle is subjected to a chemical and thermal situation similar to that occurring in the combustion chamber of a power station boiler. Fly ash production rates of up to 0.1 g/hr are maintained until a total of 15-20 g of fly ash is collected. The method has been tested by comparing the properties of fly ash from full-scale generating plants with the properties of fly ash from the laboratory micro-furnaces using the same coal.

Such studies involved:

- standard chemical analyses of the parent coal and the resultant fly ashes,
- determination of the size and specific gravity of the fly ashes using standard techniques,
- microscopic examination of the fly ashes at a magnification of 350 to determine shape and carbon distribution,
- determination of the porosity in order to provide data related to the properties of fly ash deposited on the collecting plates of a precipitator and the handling characteristics of such fly ashes,
- resistivity measurements over a range of temperatures at various moisture conditions in a flue gas environment at various electric field strengths up to breakdown,
- determination of the dielectric constant of a bulk sample of the fly ash as a function of temperature and moisture conditions in a flue gas environment,
- the determination of current-voltage characteristics in a model cylinder-wire electrostatic precipitation analyzer, under both clean and contaminated conditions at various temperature and moisture values, again in a flue gas environment.

The porosity of the fly ash, together with sizing, indicates the likelihood of aerodynamic difficulties occurring within the precipitator collection zones and the possibility of re-entrainment problems.

Determination of the resistivity of fly ash is generally considered to be of importance in assessing whether the deleterious phenomenon of back corona will occur in an electrostatic precipitator. The higher the resistivity, the lower the current density at which back corona becomes a problem. Fly ash with resistivities of less than $10^{9}\,\Omega$ meters should give rise to minimal back corona problems, whereas for fly ash with resistivities greater than $10^{12}\,\Omega$ meter, severe problems may be expected. The ACIRL resistivity measurements are carried out in a special cell so that only a small quantity of fly ash, about 10 grams, needs to be used. The cell consists of parallel electrodes, one of which is porous to allow the simulated flue gas to come into intimate contact with the ash, between which the fly ash is compacted to a depth of 5 mm Measurements of resistivity are made over a temperature range of 90°C to 200°C, for moisture contents varying from 0 to 15%, and usually with an electric field of 400 kV/m. However, some resistivity measurements are made with fields as low as 100 kV/m and as high as 1400 kV/m.

Determination of the d.c. dielectric constant of the fly ash is important since this quantity is one of the parameters which determines the ability of the fly ash particles to accept charges in a corona discharge ACIRL also feels that the high frequency dielectric constant of fly ash may be important in determining the magnitude of the charge collected by the fly ash particle because of the a.c. components of the corona discharge Measurements of dielectric constant are made over the temperature range of 110°C to 190°C at moisture contents of 0, 5, and 10% and at frequencies of 500 Hz, and 1 kHz. Dielectric constants ranging from 1.6 to 5.4 have been measured.

The determination of the current-voltage corona characteristics in the model concentric cylinder analyzer is considered to be complementary to the resistivity measurements and illustrate the effect of resistivity. Such characteristics give an idea of the magnitude of back corona that may be expected to be sustained in a precipitator when back corona is likely to be a limiting factor in particle collection. Clean chamber corona characteristics are first determined at various gas temperatures (100°C to 190°C) with moisture contents of 0, 5 and 10%. Fly ash is then precipitated in the chamber and the current-voltage characteristics are determined again. The voltages used range up to 25 kV and the resulting current densities range up to 2.5 $\mu A/cm^2$. The largest difference between the contaminated and uncontaminated cell occurs for dry gas, the contaminated current-voltage characteristic being much steeper and having a much lower corona voltage onset.

In one study, tests were carried out at four existing power stations burning four different types of coal. While coal was being fired in a power station boiler, a coal sample was taken for study in the micro-furnace and a corresponding fly ash sample was taken from the inlet duct ahead of the boiler's electrostatic precipitator. Each coal sample was subsequently fired in the laboratory micro-furnaces and the fly ash so obtained was compared with that obtained from the power station. Results, with the exception of particle size, show a close similarity between the synthetic fly ash and the corresponding one obtained from the power station. The laboratory fly ash particles are some 11 to 12 times larger than those obtained from the power station.

A paper from ACIRL investigated the question as to why the resistivity of the two types of fly ash are almost identical despite the large variation in particle size, since an earlier study had shown that the resistivity of a given fly ash does depend on particle size. To answer this question, fly ash from a power station was divided into three size ranges, and the resistivity of each size range was measured and compared with the resistivity of the composite fly ash. It was found that for some conditions, the resistivity of the smallest particles is much larger than the others. Nevertheless, the composite resistivity is not the weighted average of the resistivities of the components. Thus the electrical resistivity of a fly ash derived from a blend of coals is not necessarily the weighted average of the resistivities of the individual fly ashes. It is thus concluded that, despite the discrepancy in size between laboratory and power station fly ash derived from the same coal, the scheme proposed by ACIRL for designing power station precipitators from bore cores is valid. ACIRL points out that within one seam, the resistivity of resulting fly ashes can vary by a factor of 60, and this fact must be taken into account in the design process of the precipitator.

ACIRL has also made extensive studies of the reproducibility of fly ash resistivity determinations. The procedures used at ACIRL lead to a high level of repeatability, about 10% in the presence of moist flue gases, and can be used with confidence.

The resistivity measurement apparatus, as well as the current-voltage corona measurement apparatus, is similar to those which were developed in the Department of Electrical Engineering, Wollongong University College, New South Wales, Australia.

NOTES

[1] Electrostatic precipitation research in Japan was discussed in Volume 5, Number 1, of this bulletin. A brief discussion of some electrostatic precipitation research in Australia was also given.

ELECTROSTATIC PRECIPITATION RESEARCH AT THE DIVISION OF PROCESS TECHNOLOGY, CSIRO, NORTH RYDE, AUSTRALIA

Leon H. Fisher

INTRODUCTION

Australia has 3.5% of the world's coal deposits. The principal source of particulates in Australian cities is fly ash resulting from the combustion of coal at electric power generating plants. Since Australia has 80% of its population living in cities, and since Australia is interested in increasing its export of coal, CSIRO (Commonwealth Scientific and Industrial Research Organization) is understandably interested in studying electrostatic precipitation. Since Australian coal contains very little sulfur (Australian coal used in power plants contains 0.7% sulfur, and some Australian coal contains as little as 0.15% sulfur), Australian workers are especially interested in the application of electrostatic precipitation to low sulfur coals. However, there are no Australian companies developing electrostatic precipitators.

Dr. Edmund C. Potter was my host during my visit to the CSIRO Division of Process Technology, North Ryde, Australia where the CSIRO electrostatic precipitation research is carried out. Potter, who is Leader of the Mineral Technology Section, is an electrochemist from Imperial College and is the author of a book "Electrochemistry: Principles and Applications." He and members of his group have very unusual views about the role of resistivity of fly ash deposits in causing poor performance in electrostatic precipitators. First, these views will be described, and then work in progress at North Ryde will be discussed.

VIEWS OF CSIRO WORKERS ON ELECTROSTATIC PRECIPITATION

Workers at the CSIRO North Ryde laboratories have for years been at a loss to understand the overriding emphasis given to the high resistivity of collected dust whenever a precipitator operates at a lower efficiency than expected. CSIRO workers agree that high resistivity plays a part in poor precipitator performance but feel that there are other important factors as well which lead to poor precipitator performance.

Another aspect of precipitation technology that the CSIRO group finds puzzling is the adherence of so many precipitator designers and users to the idea that low sulfur coals produce fly ash that is difficult to precipitate. Potter feels that published papers do not support this view. Recent CSIRO work shows that there is no correlation between fly ash collection and coal sulfur level. There are coals in Australia with 2-½% sulfur that produce fly ashes that are more difficult to precipitate than that produced from another coal with only a few tenths of a percent sulfur content

The above views are interesting in view of the fact that it is commonly believed that the use of high sulfur coal (sulfur content greater than about 2.5%) prevents back corona from occurring in electrostatic precipitation of fly ash. As described in this *Bulletin* [*5*(1), 38(1980)], back corona is believed to occur when the fly ash deposited on the collecting electrodes of the precipitator has such high resistivity that charge accumulates at the surface of the fly ash deposit facing the corona wire giving rise to breakdown of the fly ash layer. This leads to production of ions of both polarities near the dust layer and gives rise to reduction in the magnitude of the charge on the particles to be deposited

Potter feels that it is now becoming clear that precipitators have some built in defense against highly resistive dusts because of the non-ohmic character of the insulating particles, and that precipitators show a remarkable resilience to back corona. But precipitator users have a great fear of back corona and believe that it is a cause of large losses in collecting efficiency, despite the fact that it is very difficult to find data in the literature to justify this point of view In larger precipitators, back corona does not occur simultaneously over more than a minor proportion of the available collecting area. Recent experiments at CSIRO have shown that high efficiency was maintained even in the presence of large back corona currents The first manifestation of back corona reduces the charge on a fly ash particle from perhaps 5000 to about 4000 electronic charges, with only a slight effect on precipitator performance resulting

Most coal used in the United States has a high sulfur content (3% to 6%) and comes from coal fields in the eastern part of the country It is commonly believed that the low conductivity of fly ash resulting from such high sulfur coal is due to surface conduction on the deposited particles of a layer of liquid sulfuric acid (Sulfurous acid has a boiling point of 105°C and cannot contribute to the surface conduction at flue gas temperatures) The sulfuric acid is assumed to arise from the catalytic conversion of SO_2 to SO_3 (about 1% of the SO_2 is so converted). It is believed that the use of high sulfur coals has led to enormous problems involving SO_2 emission. A growing awareness of SO_2 emission problems in the United States and Europe (Australia has no such problem) which electrostatic precipitators do not handle, has caused interest in the use of low sulfur coals, of which there is a great deal in the western part of the United States Such coals have less than 1% sulfur content. Up to now, however, the development of electrostatic precipitators in the United States has been carried out in connection with the use of high sulfur coals.

Potter feels that the use of high sulfur coal in the United States has led to the use of empirical methods in designing precipitators, and that these empirical methods have held up precipitator progress in the U.S. Many American engineers have been misled into thinking that precipitation of fly ash is dominated by sulfur content and that high sulfur coal precipitates fly ash well, and that low sulfur coal produces fly ash with high electrical resistivity that causes poor precipitator efficiency. Recent work in Australia has shown that there is no connection between sulfur content and precipitator efficiency. Only in recent months has the problem of fly ash with high resistivity been observed in a single type of Australian coal. The coal which does give a problem is not one which is used commercially.

One of the results of the belief in the effect of fly ash resistivity on precipitator efficiency has been the design and installation of about 100 "hot side" precipitators in the United States. Such hot side precipitators have the flue gases to be cleaned at temperatures ranging from about 315°C to 400°C, and the design is supposed to prevent the appearance of back corona. The purpose of the hot side precipitator is to overcome the resistivity problems of fly ash that does not have sulfuric acid surface conduction by taking advantage of the fact that the volume resistivity of fly ash decreases with increasing temperature. However, reports of malfunction of such hot side precipitators in the United States have been circulating. According to Potter, the situation involving hot side precipitators is a near disaster, and he is not surprised. If the difficulty with cold wide precipitators is not due to high electrical resistivity, then decreasing the resistivity might not help. In fact, raising the temperature of the fly ash may remove the surface conduction because the boiling point of H_2SO_4 is 336°C, and this is well within the operating temperature range of most operating hot side precipitators. Fresh fly ash in the hot side precipitator can be covered with lime and chalk, and these materials can act as insulating layers between fly ash particles, the volume conductivity being thwarted by such layers. If the coal happens to be low in calcium, such insulating layers may not develop. There are no hot side precipitators in Australia, although Western Precipitation tried to market them in Australia four or five years ago. (There are only one or two hot side precipitators in operation in Japan). CSIRO has been studying the surface conductivity of fresh fly ash in an effort to elucidate the above matters.

It has been found that one cannot study the conductivity of old fly ash and expect the results to apply to operating conditions in precipitators. Surface layers can dry out and give rise to different resistivities If there is no sulfur at all in coal, one will have great trouble in cold side precipitation, since some H_2SO_4 is necessary. However, only very little sulfur in coal is needed for adequate surface conduction to exist.

Potter feels that the most important aspect in increasing precipitator efficiency is to have the voltage as high as possible, since the log (1-efficiency) is proportional to the square of the applied voltage. The greatest difficulty in designing precipitators is the variation in the nature of fly ash from coal to coal, and this fact gives rise to variations in the maximum voltage which can be applied. The range in possible applied voltage depending on the nature of the coal is enormous, it can vary by a factor of two, say from 20 to 40 kV At the present time, there is no way in which the maximum voltage which can be applied can be predicted, and an outstanding problem of the large precipitator is to learn what determines the flashover voltage According to Potter, there is no clue to the answer to this question, no one knows, for example, if resistivity determines the flashover voltage.

H J White is credited with early measurements of fly ash resistivity Although he carried out these measurements at high fields, he apparently did not sufficiently emphasize this fact All that engineers took notice of was that resistivity of fly ash was measured Accordingly, the custom grew among engineers of making resistivity measurements of fly ash at low fields with the non-ohmic aspect of the resistivity of fly ash being overlooked For example, a particular fly ash from a precipitator may be measured in a resistivity cell as having a resistivity higher by orders of magnitude than it actually has in an operating precipitator Neglect of this fact has led to inconsistencies being obtained if one combines currents in precipitators with resistivities measured in resistivity cells to calculate potential drops across insulating layers Sometimes, the calculated potential drop across a dust layer exceeds the applied potential difference across the precipitator.

The important point in electrostatic precipitation is whether the resistivity of the fly ash drops with increasing electric field at a rate large enough to prevent back corona from becoming a problem. This race has been won by precipitators using Australian fly ash, except for the one type of coal mentioned above. As an illustration of this fact, in 1972 three tons of low sulfur U.S. coal were air freighted by Pacific Power Lighting to Australia. The fly ash precipitated well, but the results were not widely accepted by Americans.

We now discuss some investigations in progress of which have been completed at CSIRO North Ryde on electrostatic precipitation.

ELECTROSTATIC PRECIPITATION WORK AT CSIRO NORTH RYDE

Combustion/precipitation rig for producing fly ash

It is perhaps not surprising that CSIRO North Ryde has developed a combustion/precipitation rig for producing fly ash, as has its neighbor ACIRL (Australian Coal Industries Research Laboratory), also at North Ryde. Development of this rig started about twelve years ago. Pulverized coal is burned in a manner simulating a full-scale combustion chamber operating between 1200°C and 1600°C, and the resulting fly ash and flue gas are passed through heat exchangers to an electrostatic precipitator operated under selected conditions of gas velocity, applied voltage, temperature, and trace additive concentration. The coal can be burned at controlled rates up to 60 kg/hr for 12 hr/day in a horizontal cylindrical furnace 4.3 m long and 0.76 m in diameter. The fly ash and flue gas mixture is initially cooled to about 600°C in a fire tube boiler attached directly to the furnace and is brought to the selected precipitator temperature (in the range 100° to 400°C) in a sequence of air, water, or steam cooled indirect heat exchangers.

The precipitator has been described differently in various publications. One description states that it consists of twin parallel tubes arranged as three identical passes in series, each tube being 0.16 m in diameter and 0.76 m long, the collecting surface of the six tubes being 2.29 m^2 and the wire to collecting tube surface distance being 75 mm. Another description states that the precipitator is tubular and has electrodes of 25 cm diameter for the receiving electrode and a concentric straight wire of 3 mm diameter with a precipitator length of 3 m and a collection area of 2.34 m^2 (in the section describing probe work, the precipitator used consists of a fine wire between two plane parallel collecting electrodes). The gas velocity can be varied from 0.7 to 2 ms^{-1} and the applied voltage ranges up to 46 kv

Precipitator efficiency is measured gravimetrically Particle size determinations of fly ash are made over the diameter range up to 50 μm.

Measurements of precipitator efficiency are made with this rig with no voltage across the precipitator (mechanical efficiency) and over the full voltage range to just below flashover. It has been found possible to extrapolate the results to those obtained with full-scale precipitators, although data for full scale precipitators are difficult to obtain.

The rig is also being used to study the precipitation properties of blends of coal. The effects are non-linear.

Measurement of electrical resistivity of flv ash In situ

Experiments have been and are being carried out in which a fine wire between two electrically connected parallel electrodes forms a negative corona discharge with voltages between 15 and 40 kV Negative voltages of up to 25 kV can be applied to a thin wire probe mounted parallel to the corona wire In a corona discharge with wire to flat plate geometry, the field adjacent to the plate may be regarded as nearly uniform If a thin cylindrical conductor or probe is placed parallel to both wire and within the plane of the corona wire normal to the plate, a perturbation of the ionized field occurs in the immediate vicinity of the probe If it is desired that the probe should take up the unperturbed potential wherever in the field the probe is situated, then a particular current must pass through the probe to offset the perturbation This current can be calculated theoretically, so that, if the probe is made to pass this calculated current by connection to an independently variable power supply, then the unperturbed potential of the field at the selected location is at once identified by the probe potential.

While this method of measuring the field potential is satisfactory, it was more precise and convenient in the work described here to obtain the appropriate probe current not by calculation but by experiment, being that value of the current which yielded a set of estimates of unperturbed field potential extrapolating linearly to zero potential at the dust-free earthed plate. This same probe current was then used in supplementary tests with a dust layer on the plate deposited there by electrostatic precipitation. With the probe at selected locations near the plate, the corresponding field potentials were estimated to within a few millimeters of the dust surface, and a short linear extrapolation to the dust surface produced an estimate of the potential there. A constant current was made to flow to the probe regardless of the position of the probe.

In this way the field across the deposit was obtained, using the thickness of the dust layer as measured after the tests. The field, divided by the corresponding measured current density, then yields a value for the operational resistivity of the dust layer under the prevailing electrical conditions, the procedure being repeated for each corona voltage or other condition of interest.

The corona wire was 420 mm in length and 0.5 mm in diameter. The probe was 300 mm long and 1.28 mm in diameter. Usually, a synthetic flue gas consisting of 75% N_2, 3.5% O_2, 14% CO_2, and 7.5% water vapor by volume was used at a flow rate in the precipitator of 6.76×10^{-3} m^3s^{-1} at 120°C.

The above precipitator was supplied with a flowing sample from the main stream of fresh fly ash and flue gas produced by the CSIRO rig which has its own precipitator The measurements could be made either in the dust laden flue gas or after practically all the dust had been removed from it.

Measurements of the operational resistivity of a particular fly ash showed a resistivity falling from 10^{10} Ωm to 10^8 Ωm as the corona voltage was raised from 20 to 35 kV. In the case studied, the dust layer exhibited back corona as the applied voltage was raised above about 27 kV. The back corona current density was estimated and found to rise very rapidly with voltage according to an approximate eighth power relationship.

Potter believes that they are the only people who are measuring realistic fly ash resistivity. As mentioned above, the electrical properties of fly ash change with time. The change can occur in as little time as a day, certainly within a week a change will have taken place. It is for this reason that Potter feels that the CSIRO values of fly ash resistivity obtained *in situ* are the only ones which apply in discussing the operation of a precipitator. Not even matching the electric fields in a resistivity cell suffices. Information on the resistivities of about 10 kinds of Australian coals are now available.

Incidentally, back corona can be detected in the test precipitator. This is associated with a rise in current density from about 10^{-4} amp/m^2 to about 10^{-2} amp/m^2.

Modification of the Deutsch equation to include mechanical collection

The Deutsch equation derived theoretically in 1922 gives the collection efficiency of an electrostatic precipitator in terms of the drift velocity of ions at the collector, the gas velocity, the length of the precipitator as well as its perimeter and cross sectional area It is supposed to apply to a single stage precipitator with turbulent flow. Potter points out that one must also include the mechanical efficiency of particle collection in this formula. In a recent letter to *Chemical Engineer*, Potter and an associate point out that in the turbulent conditions of the practical electrostatic precipitator, every particle whether it is charged or not, has a significant probability of impinging on a collecting surface and staying there Electrostatic precipitators that have no applied potential difference collect a substantial proportion of uncharged particles, and mechanical efficiencies of 40% to 50% are common, with occasional cases of 70% and higher being observed This collection mechanism persists when a potential difference is applied across the precipitator.

It used to be thought that mechanical efficiencies were attributable to gravitational fallout and were almost insignificant, but experience with spherical particles such as fly ash has shown that the principal mechanism of mechanical collection is the trapping of particles following their impingement on a powder surface having cavities of sizes comparable with their own Some of these particles may wedge firmly into existing cavities or embed firmly into the surface after pushing other collected particles aside A few impacts will probably cause some re-entrainment. The smaller particles are the least likely to re-entrain others in this way and are probably the most likely to be re-entrained themselves The entire mechanical collection process can be more efficient if the particles have certain shapes, for example rods or lenses, or have sticky, or spiky surfaces.

No one so far has quantitatively analyzed these factors in the mechanical collection of particles. However, the effect is experimentally measurable and may be included by modifying the Deutsch efficiency equation to read

$$\eta = 1 - (1 - \eta_o) \exp(-Aw/V),$$

where η is the efficiency of a precipitator including both electrical and mechanical effects, η_o is the mechanical efficiency, w is the drift velocity of ions near the collecting plates, V is the gas velocity and A is a geometrical factor depending on the length, circumference, and area of the precipitator. The equation reverts to the Deutsch equation if $\eta_o = 0$. The advantage of the new equation is that η is not zero when w is zero, i.e , when the electric field is not applied. Since η_o is commonly 0.4 to 0.5, the modification is taken to be an improvement over the Deutsch equation. However, it seems to me that this equation is an empirical one since the mechanical efficiency cannot be expected to be modified by an exponential involving the particle velocity. The equation giving the effects of both mechanical and electrical collection efficiencies (they are not independent) must be more complicated than the above equation

Potter ascribes mechanical collection to the effect of turbulence. I have asked a number of precipitator scientists whether turbulence is beneficial or detrimental to particle collection in an electrostatic precipitator. They have all answered that turbulence is detrimental, with the exception of Potter, who feels that some turbulence is beneficial but that too much causes re-entrainment. Perhaps this is an academic question, since all precipitator gas flow is turbulent. However, it would seem to be an important question to resolve.

Use of the extended Deutsch equation by CSIRO

The effect of applied voltage and particle size is not explicitly described by the Deutsch equation, these effects are manifested through their effect on the ion velocity. These effects were explicitly inserted into the Deutsch equation about 14 years ago for the first time and led to what is now known as the extended Deutsch equation The extended Deutsch equation has been heavily used by the CSIRO group to analyze their precipitator efficiency measurements. The essential point is that Stokes' law is used to connect the electrostatic force on the particle with the viscous drag. One has to use the theory of Pauthenier to determine the charge on the particle, for this one also needs the dielectric constant and the size of the particle. Usually, the extended Deutsch equation is taken to involve the voltage and the specific collection area (collection area per unit gas throughout volume per unit time) The remaining factors are usually given in terms of an undetermined constant. At any rate, the extended Deutsch equation leads to the expectation that the log (1-efficiency) plotted against the product of the square of the voltage and the specific collection area is a straight line, called a "performance" line. This method of analysis emphasizes the importance of the voltage, since the semi-logarithmic dependence is a quadratic one. The performance line indicates the effects of gas additives by changing the slope of the curve for a given voltage, and by allowing the precipitator to operate at a higher voltage than without the additive, if the additive has a beneficial effect

Investigation of Carrier Gas Additives

Flue gas additives were tested on the combustion rig for possible improvement of precipitation efficiency Additives included sulfur trioxide, ammonia, and organic amines Of these, the most successful has been triethylamine, $N(C_2H_5)_3$, commonly given the acronym TEA. TEA raises the collection efficiency for a given applied voltage, and also allows higher voltages to be applied before flashover occurs. The increased efficiency at a given voltage is attributed to clustering of colliding dispersed particles following the reaction of adsorbed triethlylamine with sulfuric acid present on the fly ash surfaces. The clustering causes an effective increase in particle size and corresponding improvement in collection efficiency TEA selectively improves the efficiency of collection of the smaller particles, in keeping with the idea of clustering TEA is being used successfully in full-scale coal fired power stations in Australia, and at an addition rate of 10 ppm by weight on the flue gas is an economic way of reducing fly ash emissions. Triethylamine is capable of stopping back corona, and is due to the same enhancement of insulation that allows precipitators treated with TEA to operate at higher voltages However, a precipitator does not have to be suffering from back corona to be improved by the addition of TEA

Chemical composition of fly ash surfaces

Potter discusses this topic in a paper and states that the results are those of P. J. Collin, "Some Aspects of Fly Ash Surfaces," proceedings of the symposium on "The Changing Technology of Electrostatic Precipitation," Adelaide, South Australia, November 8, 1974.

Fly ash resulting from the combustion of bituminous coal is essentially a glassy aluminosilicate containing significant quantities of combined iron, alkali, and alkaline earth metals. It is now emerging that the bulk composition of the ash differs from its surface composition. It is found that the surface layers of freshly formed fly ash, as delivered to the precipitator at up to about 200°C are acid, even though the eventual result of suspending the collected fly ash in distilled water may be a decidedly alkaline solution. Selective aqueous dissolving of the successive layers of fly ash produced from low sulfur (less than 0.1%) coal shows that the first few molecular layers consist of strong sulfuric acid. Immediately beneath this is a comparably thin layer of calcium sulfate, which is the result of reaction between the outermost acid and lime that forms the innermost water soluble material. In most cases studied, the lime is in excess of the acid and the initial acid reaction of a slurry of fly ash in water gives way within an hour to an alkaline reaction, the final pH value, sometimes greater than 11, being reached within 24 hours.

Fly ash surfaces age on keeping, principally because the sulfuric acid layer gradually disappears by volatilization, or more commonly by neutralization. Since the acid layer plays a useful role in conducting precipitator current, the use of recovered or washed fly ash for precipitation experiments is invalid and may yield quite misleading results.

COMPUTER INDUSTRY IN JAPAN: FUJITSU LTD.

Y. S. Wu

On 23-25 July 1980, the author visited Fujitsu Ltd., including the computer manufacturing complex in Numazu and the R & D engineering center (Kawasaki Works). Established in 1935, Fujitsu today is a vertically integrated computer company. Its product line spans basic research in semiconductor component technology to complete computer, peripheral products and software systems. Its 1980 annual sales of U.S. $2.5 billion and its 33,000 employees give a very attractive sales to employees ratio. This is only surpassed by the industry giant, IBM, which Fujitsu is enthusiastically emulating. Like IBM, Fujitsu aggressively markets its entire product line worldwide

NUMAZU COMPLEX

Various functions at Numazu are distributed among six zones The "Hardware Zone" manufactures large- and ultra-large-scale computers, including the FACOM "M" series, the all-LSI CPU computer series. In the adjacent "Software Zone" the latest basic software for high reliability, high-quality computer programming is developed. The "International Institute for Advanced Study of Social Information Science", a very much future-oriented body dedicated to wide ranging research into the shape and structure of tomorrow's informationized society, is located in the "Research Zone" at the other end of the premises, close to the excellently equipped "Residential Zone". In the far corner of the site is the "Recreational Zone". When construction is fully completed it will contain a clubhouse, a gymnasium, soccer and baseball fields, and tennis courts. However, even after the final construction stage, all these zones will occupy only 9.3% of the overall 530,000 square meter site, the remainder comprising an unspoiled "Green Zone" and tea plantation.

At the heart of the Numazu Complex is the No. 1 Building of the Hardware Zone, the most advanced computer assembly plant in Japan, if not the world. This building specializes in the assembly of large- and ultra-large-scale computers.

A noteworthy feature of the building is its vertical division into production and administrative sections, in order to increase the smoothness and accuracy of the production process. Another characteristic is the voluminous floor space, fully adequate for production expansion expected in the future.

Throughout, the building benefits from total automation and a high degree of labor saving due to the installation of automated control systems in all equipment on every floor, and an online production system integrated with other related plants. System testing is facilitated by the free access area designation of the first- and second-floor testing shops

Products manufactured in the No. 1 Building include the FACOM "M" series, the large-scale 470V/6 computer for the Amdahl Corporation of U.S.A. and two M-200 series for Siemens of Germany.

The "top-down" floor layout is as follows 6th floor-parts inventory, 5th-printed circuit board assembly, 4th-unit assembly, 3rd-office, test software & computer center, 2nd-system test, 1st-final test and shipping.

Numazu complex is Fujitsu's consolidated manufacturing facility for its entire computer product line FACOM M-Series. It has been an established fact that no significant new innovation in computer architecture has been witnessed during the past two decades. All computer architectures are "variations on a theme". It is not surprising that in careful and premeditated planning, Fujitsu elected to make the M-Series "Internationally" compatible with the other "Business Machine" company in the United States to avoid the long development time and prohibitive cost of system software development The M-Series is CPU compatible with IBM 370 Series computers. Furthermore, their operating systems are compatible with corresponding IBM system software For instance, FACOM OS IV/F4 is upward compatible with IBM/OS/VS2 The same relationship exists between FACOM OS IV/F2 and IBM DOS/VS This compatibility is detailed in

Table 1. However, the Fujitsu pricing strategy is to offer approximately twice the IBM performance at the same price given the same software support. This price performance comparison is depicted in Figure 1.

In addition, Jujitsu manufactures all Amdahl (25% Fujitsu-owned U.S. firm) 470V Series (M-180 equivalent) computers and top of line Siemens (M-190, 200 equivalent) computers for sales in Germany. The Fujitsu sales growth for the last decade is shown in Figure 2. The Numazu complex is the most modern computer manufacturing facility this author has ever toured.

KAWASAKI WORKS

The Kawasaki Works is within the great metropolitan area of Tokoyo. It was first established in 1938 This is Fujitsu's engineering center where innovative R&D in both the computer and telecommunication fields is carried out. The center also pursues reliability, maintainability, and production technology research. One of the most impressive accomplishments of Kawasaki is the rapid technology transfer from R&D laboratory to marketable products. Some of these products are described below:

64 Kbit RAM

In 1979, Fujitsu introduced N-channel MOS dynamic random access memories (DRAM). Fujitsu's 64 Kbit DRAM features a 144 mm^2 cell and a 21.5 mm^2 chip area. While this represents an area increase of approximately 20% over the 16 Kbit DRAM, its memory capacity has been quadrupled.

The 64 Kbit DRAM chip is mounted on a 16-pin dual inline package (DIP). Compared with the 1 Kbit DRAM first introduced in 1970, per-bit area and energy consumption have both been reduced to 1/100th, while access time has been halved to 150 ns.

CMOS Microprocessor

A new CMOS 16 bit microprocessor equivalent in complexity to some 10,000 gates on a single chip is available. Dubbed the FSSP (Future Small System Processor), this advanced LSI product is already in use in small-scale computers.

The FSSP is comprised of a microprogram-controlled 16 bit processor with two internal parity bits. Using high-density, high-speed CMOS technology, data storage RAMs and processor logic are contained on a 100 mm^2 chip. The FSSP can also directly access up to 16 MB memory, including a virtual storage function. The processor instruction set includes decimal and floating instructions.

Despite its high integration level, the FSSP consumes only 130 mW. Furthermore, internal gate delay time is 4-7 ns with internal calculation speeds as fast as 230 ns (memory/ALU/memory).

1 Mbit Bubble Memory

Fujitsu is preparing sample shipments and mass-production procedures for its newly developed 1 Mbit bubble memory device. The new 1 Mbit bubble memory device is designed to serve as a program memory, mini-file memory and as a file memory for terminals and other equipment.

Fujitsu entered into bubble memory development in 1970 It currently markets 64 Kbit and 256 Kbit bubble memory devices as nonmechanical file memories. In June 1980, Fujitsu completed its all-LSI support circuitry, thereby permitting bubble memory cards offering enhanced miniaturization and reliability

Among its bubble memory products, Fujitsu also markets a bubble cassettte to replace paper tape and card readers as program loaders in test equipment. This bubble cassette is currently offered in 64 Kbit and 256 Kbit models.

Following sample shipment and mass-production development of its 1 Mbit bubble memory, Fujitsu is preparing to move toward the development of a 4 Mbit memory.

Optical Semiconductor Devices

Fujitsu currently offers a wide range of high-performance optical semiconductor devices. In the 0.8 micron wavelength region, Fujitsu's light source selection includes AlGaAs LDs (laser diodes) and AlGaAs LEDs (light emitting diodes), while in detectors Si APDs (avalanche photodiodes) and Si PIN, photodiodes are now commercially available.

Fujitsu's AlGaAs double heterostructure LDs are designed as light sources for optical communications in the 0.8 micron wavelength region. They feature a 15 mW output, stable cw operation over a temperature range from -40 to +70 C, a 10^5-hour operating life at an output of 5 mW at room temperature, and monitoring optical output for automatic power control.

Fujitsu's 0.8 micron LEDs with a cut-off frequency of 30 MHz have an output capability of more than 200 microwatts coupled into a 0.17 N.A. 85 micron step index fiber at 100mA. The LEDs with a cut-off frequency of 100 MHz are also available. Their operating life at room temperature is estimated to be over 4×10^7 hours.

In optical detectors, Fujitsu's Si APDs are hermetically sealed with a sapphire window; a quantum efficiency of 80% has been achieved, with an excess noise factor $F = 4$ at a multiplication of $M = 100$.

In addition to its 0.8 micron region products, Fujitsu is also engaged in the development of a full variety of optical devices for the 1 micron wavelength region. InGaAsP LD's and InGaAs photodiodes are presently under development for application in the near future.

Fujitsu's 1 micron InGaAsP LEDs are capable of 50 W output at 100 mA when coupled into an 85 micron step index fiber. Their cut-off frequency is typically 30MHz. Operated at room temperature, these LEDs offer an expected half-life of up to 109 hours.

For the 1 micron wavelength region, Fujitsu's Ge APDs feature a quantum efficiency exceeding 60% and an excess noise factor of $F = 10$ at $M = 10$. Their cut-off frequency is 600 MHz, with a light detecting capability through the 1.6 micron wavelength region.

Integral Fiber Branching Filters

Integrating its standard optical semiconductor technologies in the areas of coupling, connectors and peripheral circuitry, Fujitsu has developed a full lineup of optical fiber link modules. These modules are incorporated in Fujitsu's series of optical fiber link systems, which include 1.5 Mb/s-32 Mb/s digital models and 6 MHz-30 MHz analog models

Fujitsu has also completed development of a wide range of high-reliability connectors, couplers, branching filters, switches, attenuators and other passive components designed to support its optical transmission systems

GaAs FETs

Fujitsu developed the normally-off GaAs IC in 1977. Fujitsu currently offers a range of GaAs FETs, from 2 to 20 GHz, including power GaAs FETs in the 4 to 12 GHz range. The 8 GHz power FET, for example, features a power output exceeding 10W. Fujitsu power GaAs FETs provide a power-added efficiency of greater than 40%. Fujitsu's new devices currently under development are its GaAs linear IC and GaAs digital IC. When completed early in 1981, the GaAs linear IC will be able to serve as a microwave subsystem only 4 X 4 mm in size. This will represent a 1,000-fold reduction in volume compared with conventional subsystems incorporating discrete GaAs FETs The new GaAs linear IC will have the additional advantage that it will be applicable to a variety of frequency ranges (2-4 GHz, 4-12 GHz, 12-18 GHz), thereby achieving subsystem standardization.

Fujitsu's new GaAs digital IC, on the other hand, is being developed as a logic IC for super high-speed large-capacity computer systems. Employing the normally-off operation mode, Fujitsu's GaAs digital IC is to feature 6 to 10 times the speed capability of conventional silicon-based ICs, while attaining reduced power dissipation A performance of 70 psec/gate has already been achieved. Future plans call for development of a GaAs digital IC offering the high speed of the Josephson junction at room temperature

SUMMARY

Fujitsu manages to move a product from R&D to production in 3 to 7 years, whereas in the United States the typical delay is 5 to 10 years. This means, among other things, that the Japanese could begin their research and advanced development based on U.S. publications and still beat us to market. They do *not*, however, have to rely upon U.S. research results. It is significant to observe that Fujitsu as a policy assigns one researcher who makes a discovery with the responsibility to move that discovery through to production. A successful researcher at Fujitsu must make several round trips from research to production during his career.

REPORT ON VISIT TO SEVERAL JAPANESE LABORATORIES: DEVELOPMENT OF HETEROJUNCTION TRANSISTORS BY MOLECULAR BEAM EPITAXY

Herbert Kroemer

In Fall 1980, I visited several Japanese laboratories active in molecular beam epitaxy (MBE) or in related heterostructure research.

SONY

I had been specifically invited by Dr. Kikuchi, Director of Research for Sony. This invitation matched my own desire to learn more about Sony's work on two topics:

- Antiphase domain boundaries (APDB) in GaP-on-Si and Ga-As-on-Ge epilayers,
- Si heterojunction transistors made by deposition, on Si, of "semi-insulating polycrystalline" sillicon (SIPOS; actually, it is extremely heavily Phosphorus-doped amorphous Si, but with low P activation).

On the first item, no additional work since Morizane's paper has been done; the only additional information was that the APDB's commonly observed in (100)-oriented growth would disappear for substrates oriented off the exact (100) direction by "a few degrees." Sony is pushing the second topic hard, and is having good success. Two earlier papers (Appl. Phys. Lett. 1979; IEDM 1979) were followed by a third paper presented (in Japanese) at the Tokyo Conference Solid State Devices (CSSD); details will appear in print early in 1981 in the conference proceedings (Jpn. J. Appl. Phys. Suppl.).

Inasmuch as there is a considerable question about the high-frequency capability of this combination, I asked whether they had high-frequency data. Yes, the devices, apparently not optimized for microwaves, had $f_T \cong 2$GHz! Pressed whether this was a direct measurement at 2GHz or extrapolation of much-lower-frequency data, they said it was extrapolation of data up to 1 GHz. I was not shown actual data, nor were any further details given. I do not believe that they were holding anything back, the whole discussion rather suggested that this was a somewhat casual measurement, done within the limits of the techniques readily available in a laboratory that is not especially oriented towards microwave devices. I believe one should take their claims at face value, and make additional allowance for the possibility of future improvements by optimization of technology, device geometry, and packaging. If this optimization goes sufficiently far, this approach would be more attractive than our own MBE-grown GaP-on-Si approach towards a microwave bipolar technology that is compatible with standard Si technology. I strongly recommend that someone in the U.S. interested in MW devices should sponsor SIPOS-on-Si MW device research, in direct competition with our GaP-on-Si approach, which should continue.

ELECTROTECHNICAL LABORATORY (ETL) UNDER MINISTRY FOR INTERNATIONAL TRADE AND INDUSTRY (MITI)

Located in Tsukuba, about one hour north of Tokyo, this is a very large (700 people) government laboratory in brand-new facilities, they just moved there from Tanashi (Tokyo) a few months ago. It was one of the laboratories that had published some of the most impressive and imaginative MBE work in Japan, including the first GaP-on-Si MBE work (Dr. Gonda), and some extraordinarily impressive ZnSe MBE work). A visit there was a must for me, it was well worth it. I lost count of the number of people involved, but they do MBE or quasi-MBE ($p \lesssim 10^{-5}$ Torr) on more materials than anybody else I know of: AlN (on Si and Sapphire), SiC, NbN, ZnSe, Si (on Si), GaP (on Si). I kept detailed records only on the latter three. Extensive attempts to dope ZnSe beyond the high as-grown conductivity (especially p-type) have not been successful. I was shown the equipment, it was competently designed, home built, very functional, no "gold-plating," no surprises. The Si-on-Si work (Dr. Sakamoto) was of interest to me principally because they are using our Ga-beam Si de-oxidation technique (at 900°C rather than 800°C) with excellent success. Dr. Sakamoto apparently tried to please me (and did!) by having the equipment set up to show me the electron diffraction patterns of Si surfaces obtained by our Ga-beam technique, they looked superb indeed. The equipment (for some obscure reason inside a clean room) was remarkably simple; home-built and without frills. The GaP-on-Si equipment was even simpler, to the point that they appeared to be reluctant to show it. They should have been proud instead!

Dr. Gonda's GaP/Si work has been taken over by Dr. Sakamoto. Gonda had started (apparently for reasons similar to ours, to avoid antiphase disorder) with (111) orientations, which did not work as well with MBE as with VPE (Vapor Phase Epitaxy) Sakamoto did the fairly obvious switch to a (100) orientation, and investigated the T_S-dependence of the growth morphology (unpublished). Now here's the stunner Best morphology between 300° and 400°CC!! I was shown detailed data about this totally counter-intuitive result, and they are convincing We have since then confirmed this result on both (100) and (110) orientations. This brief episode probably saved us 2 months of work!

Asked about the motivation for their interest in GaP/Si, they stated LED's on a cheap substrate, *not* transistors. They specifically stated that they never attempted a transistor, even though they were fully aware of the idea. Their use of a (100) orientation makes this claim quite believable.

I was offered a chance to look at a just-arrived Varian MBE system almost identical to ours, not yet in full use. I declined, to everybody's amusement, and nobody's surprise. It was late, I wanted to catch a reasonable train back to Tokyo. More important: I was totally saturated.

This is a very fine research group, and they were completely open about their work.

TOKYO INSTITUTE OF TECHNOLOGY (TIT)

Professor Takahashi and his students are another group that had published outstanding MBE work and other heterostructure work, and I looked forward to a visit. Unfortunately, there was too little time for an in-depth discussion of Takahashi's own MBE work. Knowing my role as originator of the DH laser concept, and knowing that the NEC Central Research Laboratory, with its most impressive DHL work, was not on my visiting agenda, he had arranged a visit to NEC for me the same afternoon, leaving too little time for himself. Still, in what little time we had, I was given an ultra-efficient laboratory tour, with opportunity to take a detailed look at two MBE (and one MOCVD) systems, and to receive answers to most of the questions I wanted to ask, there was absolutely no language barrier The two systems were again well-designed, home-built systems, containing everything one really needs, and nothing one does not (*all* MBE systems I saw in Japan had air locks, mostly of various bellows designs). Most current work is on (Ga, In)As, ZnSe and ZnTe. One impressive result was a fairly bright visible-light (greenish-white) LED made by MBE growth of ZnSe on GaAs, covered with a transparent Au electrode. Works by impact ionization of impurities at surprisingly low voltage (5-6 V!). Similar results have been achieved at ETL.

NIPPON TELEGRAPH AND TELEPHONE (NTT)

There are several laboratories in Japan that have published a few papers each on MBE, but whose work is not as well known as that of ETL or TIT. I had left one day of my schedule open, for last-minute arrangements (to be made during the CSSD) for a visit to one or another of these additional places of activity Fujitsu and/or NTT quickly emerged as the places to select. One of the conference organizers got me in touch with Dr Suzuki of NTT, and I was invited to visit there [illegible]. It was extraordinarily worthwhile Two separate research groups of about three people each are investigating MBE growth of several compounds and alloys, using two different MBE systems. Both are home-designed (again no frills), the most recent one was custom-built for them by ANELVA, and it shows the Varian influence (the "VA" in ANELVA) A large part of their effort goes into (Ga, In)As on InP They use a premixed Ga/In source, with an auxiliary (weak) In source to make up for the depletion of In from the mixed source This replaces the separate In and Ga sources that they reported in their published paper Ga In ratio control is by quad, with careful ion gauge control of As_4 background pressure (it changes the Ga In ratio sensitivity of the quad) They grow InP buffer layers first, using elemental P as a P_4 source They have no end of trouble with this (baking after every run), and this led to a lengthy discussion of P_2 vs. P_4 sources I decided to be quite open about our preference for a P_2 source, and was rewarded by a complete openness on their part in the discussion throughout the remainder of my visit They have done considerable work on GaSb and InSb, largely unpublished, on which I was given considerable information that would go too far for this report The stunner was their work on GaSb/AlSb superlattices with a 400 Å period Photoluminescence data suggest a flat valence band, in good agreement with both the Frensley-Kroemer and the Harrison theory

All in all, this visit was every bit as worthwhile as that to ETL

WASEDA UNIVERSITY (Professors Kimata and Itoh)

This is not one of the big-name laboratories; I had invited myself there largely because of the high quality of the relatively few papers they had published, including particularly an excellent paper on the MBE growth of InAs, a matter of specific interest to me. They have since then moved on to InSb, on which they have done similarly excellent work, which is also published, but which I had somehow missed. All of their excellent work was done on a home-built "string and sealing wax" MBE machine that was humbling in its utter simplicity. Somehow this place seems to have been overlooked by the Japanese research funding agencies. But a couple of professors with a bunch of energetic and enthusiastic grad students, and with imagination and a seemingly unlimited genius for improvisation, make up for what they lack in Auger spectrometers, separate analysis chambers, computer control, and what have you. Four sources, one multi-hole disc shutter operating the four sources independently with a single rotary feedthrough (!), the obligatory airlock, and a RED system, that is all. And even the real-time RED is new; their InAs work was done with a separate electron diffraction setup. I suppose our own Phi's, Riber's, and Varian's with all their glittering gimmickry buy us better and more reproducible purity, but anybody who thinks that there is no place left for people with limited equipment, with only ideas and imagination, should visit Waseda University.

FOURTH INTERNATIONAL CONFERENCE ON TITANIUM

Philip J. Dudt

The Fourth International Conference on Titanium is the most recent of the international conferences on titanium which occur every four years. The conference from 19 to 22 May was held in Kyoto, Japan at the Kyoto International Conference Hall. The Conference Hall provided excellent facilities as well as a very pleasant setting. The roughly 450 attendees represented a wide range of interests from producers, spot buyers, aerospace, academia, nuclear power, medical technology and other diverse applications in which titanium finds use. The conference was well attended with significant participation from all major producer/user countries except the Soviet Union which sent only a few delegates. The conference was very well organized and translators did an excellent job. A 400-500 page book of extended abstracts was provided to each participant during the registration.

The first item of business was keynote addresses from each of the major titanium producer/user countries, the USA, the USSR, Japan, the UK, France and West Germany. Following these presentations, the titanium situation for the world was summarized.

Ward Minkler of Titanium Metals Company of America presented the U.S. picture. He noted the unprecedented demand for titanium in the U.S. with record shipments to all market sectors. Production last year had been a record 19,599 tons, However, Minkler felt the shortages of titanium would ease because production of F-14 and F-15 fighter aircraft was peaking which would bring down demand. Opportunities for titanium in the 1980's appeared good. There were new benefaction processes. Use of electrowinning along with continuous casting techniques would be implemented. Intermetallic compound based alloys would find increased application at high temperatures. Greater amounts of titanium would be used in heat exchangers and power plants.

A. F. Belov of the Soviet Academy of Sciences gave his evaluation of the Soviet industry. The recent demand for titanium in the USSR was also very great. The increase in its use had amounted to about 50 percent in 5 years. One ton of titanium in civilian industries could save 9000 rubles. The Soviet Union was able to produce complex titanium products with different microstructures and provide specialized testing services. The USSR had focused on a significant effort to bring down titanium costs through improved melting methods, powder metallurgy, and joining by diffusion bonding. In the future the Soviets would fabricate parts from evaporation techniques, increase the level of effort in powder metallurgy and emphasize intermetallic and high-rate solidification alloys.

Kokichi Takahashi, president of Kobe Steel, Ltd., gave the keynote address for Japan. Demand for titanium in Japan is currently very heavy. Titanium is needed for new types of commercial aircraft, for lighter, quieter engines and in thermal and nuclear power stations. Last year Japan produced 13,200 tons of sponge and this year was expected to produce 17,000 to 18,000 tons, in 1981, 22,000 to 23,000 tons. Current Japanese production capacity is equivalent to that of the U.S. at 22,500 tons. (The Soviet Union has the highest capability at 35,000 tons.) Japan had made a significant effort to cut down the power requirements for titanium production Japan's primary applications in the past had been geared to the chemical and power industry as opposed to aerospace in other countries. Takahashi felt that titanium would find increasing use in other new applications in the future. As examples, he showed pictures of a deep submergence vehicle and a magnetically levitated train.

Additional presentations were made on UK, French and West German industry The British who are primarily concerned with aircraft and aircraft engines stressed these areas feeling there was a large market in military and new wide body civilian aircraft. They were also experiencing large demands for titanium material The French speaker stressed newer melting processes and emphasized power metallurgical techniques A new French process produced superior powders through electron bombardment. Germany utilized titanium primarily in the chemical industry Because of their heavy dependence on foreign producers for the metal, they were considering going into sponge production The high prices now being charged could lead to material substitution and in the long run be detrimental to the industry

R. Jaffee of the Electric Power Research Institute commented on the worldwide titanium situation. From the 1955 time period titanium had gone from a purely military material to the point where 50 percent of the production went for commercial applications. Titanium assumed special importance because the world's supply was nearly inexhaustible, and it could replace stainless steels and other alloys which contained elements in short supply. High quality titanium could be produced by 3 methods; magnesium or sodium reduction and electrolytic. The electrolytic process required about 40 percent less energy than the magnesium or sodium reduction methods. Jaffee presented a breakdown of titanium product forms. In his table, powder metallurgy and casting were only on the order of one percent because these methods were still limited, and only in the development stages. The speaker covered new heat treatment processes and joining by diffusion bonding.

At present the Ti-6Al-4V alloy dominated the market at 52 percent and commercially pure titanium at 29 percent. Tendency was toward a fewer number of alloys to decrease costs. However, some new alloys were being developed for engines. The Ti_3Al and Ti-Al intermetallic series were examples.

Unsolved problems in titanium were hydrogen migration over long time periods, room temperature creep, hot salt corrosion, and combustion problems at high temperature.

Long term prospects for titanium were excellent.

The remainder of the conference was devoted to various sessions which specialized in one particular area of titanium technology. Generally two sessions ran concurrently. The method by which papers were presented was by the rapporteur system. The rapporteur would be tasked with bringing together or summarizing all the papers in a session in an hour or less presentation. Questions to the individual authors who sat around the podium followed. Use of this approach, while it suffers some disadvantages, gives benefits when given technical experts can summarize a number of papers into a more meaningful whole. Over 300 papers were presented at the conference.

Sessions for the first day were entitled "Commercially Pure Titanium on Surface Condensers and Chemical Equipment" and "Titanium Alloys in Aerospace Industry and Other Fields." The subject of condensers generated a great deal of interest, particularly from the nuclear energy field. The long term reliability of titanium can give significant safety and life-cycle cost advantages over other materials. Hydrogen absorption/concentration is an area of special consideration in this context however. Hydrogen migration to highly stressed areas could produce zones of weakness and propensity for brittle failure. Long term hydrogen absorption was not observed in the session reports. In the second session many diverse investigations from rocket motor cases to medical implant applications were reported on.

Two concurrent sessions were the rule for the remainder of the conference. The subject matter for the sessions of 20 May were of two general types: rather basic research of scientific interest on metal physics and behavior, and those of primary significance to the production/fabrication of titanium. These sessions were separated accordingly. The topics in the first category were diffusion and internal friction, lattice defects, crystallography and physical properties, deformation, texture and superplasticity and creep. In these sessions there was notable interest in superconductive alloys of the Ti-Cb class. There was interesting research on micro-alloying to improve titanium properties. Many of the papers in the sessions and throughout the conference focused on British alloy IMI 685 a Ti-Al-Zr-Mo-Si composition which is replacing Ti-6Al-4V in a number of applications. In the second category the following topics were covered extractive metallurgy, specification and test methods, fabrication methods, and powder metallurgy and composites.

The sessions of 21 May were in a number of areas of interest, many interrelated, but could roughly be divided into those of more basic research and those of more significance to the user/producer. These were separated accordingly. The more basic research areas were concerned with mechanical properties and phase transformations and heat treatments The others were on metal working, corrosion and oxidation, and a very popular session on the application of titanium in electric power stations In the more basic research interest included microstructures for improved fatigue performance and strength, improved heat resistance, memory alloys, amorphous alloys, and alloys containing titanium as less than a major constituent.

The concurrent sessions focused on titanium hard facing, extrusions, forgings, corrosion problems (chemical industry), oxidation mechanisms (turbine technology), and use of titanium as noted before in conventional and nuclear power industry.

The final sessions were in the morning of 22 May and concerned fracture and fatigue of titanium structures. Concurrently investigations of phase stability and equilibria were reported. The fracture and fatigue areas assessed both micro- and macro-mechanisms in alloy titanium. Hydrogen content, surface condition, manufacturing method and local microstructural variations were considered. Phase equilibrium and stability of a number of complex alloys were covered.

The conference provided in-depth evaluation of the multiplicity of applications in which the relatively new metal titanium is finding use. It was decided that the next conference in 1984 would be held in Munich, Germany.

FOURTH INTERNATIONAL CONFERENCE ON TITANIUM

R. Yoder

The Fourth International Conference on Titanium was held 19-22 May 1980 at the Kyoto International Conference Hall in Kyoto, Japan. The conference was sponsored by the Japan Institute of Metals, in association with societies from the United States (American Society for Metals and The Metallurgical Society of the American Institute of Mining, Metallurgical and Petroleum Engineers), the United Kingdom (The Metals Society), the Federal Republic of Germany (Deutsche Gesellschaft fur Metallkunde), France (Societe Francaise de Metallurgie) and the U.S.S.R. (The Academy of Sciences U.S.S.R.). The International Organizing Committee, chaired by H. Kimura of the National Research Institute for Metals (Japan), included three representatives from the United States. Conference co-chairman J. C. Williams (Carnegie-Mellon University) and Harold Margolin (Polytechnic Institute of New York), both prominent ONR contractors, and E. F. Bradley.

This conference, the latest of a quadrennial series, follows those held in Moscow (1976), Boston (1972) and London (1968). There were approximately 500 registrants for the conference in Kyoto from 24 countries, with approximately 275 of the participants from Japan and 65 from the United States.

The conference program was comprised of keynote lectures, critical reviews, and about 300 papers that touched upon virtually all facets of the technology of titanium-based materials, from basic research to the applications end of the spectrum. In view of the sheer numbers of papers—as well as the fact that parallel sessions foreclosed the possibility of hearing all of them, no attempt will be made here to review all of the papers presented. Moreover, early publication of the Proceedings of the Fourth International Conference on Titanium is anticipated before the end of March 1981 (in four volumes, of approximately 4000 total pages).

In the Introduction and Keynote session, authorities from the United States (W. W. Minkler of TIMET), the U.S.S.R. (A. F. Belov of Academy of Sciences U.S.S.R.), Japan (K. Takahashi of Kobe Steel, Ltd.), the United Kingdom (T. W. Farthing of IMI Ltd.), France (P. Lacombe, Universite de Paris–Sud) and the Federal Republic of Germany (W. Knorr of Friedrich Krupp GmbH) presented keynote addresses on the titanium industry in their respective countries, followed by an Overview presentation by R. I. Jaffee of the Electric Power Research Institute (U.S.A.). Several observations from these experts focused on the current, unprecedented demand for titanium and its alloys that is experienced worldwide – a demand prompted in no small part by the *energy savings* and increased component life that can be realized in applications which take advantage of the superior strength-to-weight ratio and corrosion resistance of titanium and its alloys.

Jaffee indicated that titanium, plentiful as the fourth most abundant metal in the earth's crust—there are an anticipated 400 years worth of reserves—and its alloys are prime candidates to replace stainless steel after the turn of the century With increased sponge production, he expects that 1-5 years will pass before production catches up with worldwide demand for titanium. However, he expressed concern that increased usage of titanium in the long term may well rest upon development of less costly alternatives in processing Jaffee mentioned that by 1979, military aerospace applications had decreased to 45% of total production (from 94% in 1955), while commercial aerospace applications increased to 35% and other industrial applications to 20%.

Relative to usage in commercial aircraft, Minkler noted huge orders for new lighterweight aircraft (to lower fuel costs) He further noted that the growth of industrial applications is currently at a 17% annual rate In the course of the 1980s, Minkler expects that reduced demand for military and aerospace applications will help level off the supply and demand situation in the United States, even though increased use is anticipated for steam turbine blades, medical prosthetics, commercial aircraft, heat exchangers and marine-related applications.

Belov, who indicated about a 50% increase in U S.S R. titanium production from 1975 to 1980, described advances in processing methods, from diffusion bonding to 20-m foil production by vacuum deposition in hard-to-deform alloys

Takahashi noted that the titanium industry in Japan has been geared primarily to the production of commercially pure titanium for corrosion-resistant applications in the chemical and other nonaerospace industries–in contrast to experience in the U.S and European countries. Consequently it was not surprising to find that 10 of the 13 papers in the subsequent session on Commercially Pure Titanium in Surface Condensers and Chemical Equipment were authored solely by Japanese investigators–and an eleventh was coauthored by a Japanese However, he expects increased demand for alloyed titanium in the domestic production of commercial aircraft and other applications. Takahashi mentioned that titanium alloys are being used in Japan for steam turbine blades and for deep-submergence vehicles for oceanic research

Farthing, who indicated a very great demand for aircraft applications in the United Kingdom, noted alloy development programs for new jet engine materials. One such material, the new creep-resistant titanium alloy, IMI 829 (Ti-5.5Al-3.5Sn-3Zr-1Nb-0.25Mo-0.3Si), was described in subsequent sessions in three papers by authors from IMI Titanium, IMI Kynoch Ltd., and Rolls-Royce Ltd.

LaCombe referred to processing developments, from microstructures obtained by centrifugation to hot-isostatic-pressing of metal powders. He indicated that in nuclear reactor applications, titanium is now supplanting the use of copper and nickel alloys in France.

Knorr described applications in the Federal Republic of Germany, from welded tubes for power generation plants to heat exchangers and commercial aircraft.

Following the Introduction and Keynote session, conference papers were presented in the following twelve categories, with subdivisions as indicated (names in parentheses identify authors of critical reviews):

Applications of Titanium and Titanium Alloys

- Commercially Pure Titanium in Surface Condensers and Chemical Equipment
- Titanium Alloys in Aerospace Industry and Other Fields

Physical Phenomena and Properties (E. W. Collings, Battelle Memorial Institute, U.S.A.)

- Diffusion and Internal Friction
- Lattice Defects, Crystallography and Physical Properties

Deformation (O. Izumi, Tohoku University, Japan)

- Deformation Dynamics
- Texture
- Superplasticity and Creep

Mechanical Properties (P. J Postans, Rolls Royce Ltd., United Kingdom)

- Mechanical Properties I
- Mechanical Properties II

Phase Transformations and Heat Treatments (Y. Murakami, Kyoto University, Japan)

- Precipitation
- Phase Transformations and Heat Treatments

Fracture, Fatigue and Wear (H. Margolin, Polytechnic Institute of New York, U.S.A., J C Chesnutt, Rockwell International Science Center, U.S.A , G. Lutjering, Ruhr-Universitat Bochum, F R Germany, and J C Williams, Carnegie-Mellon University, U.S A)

- Fracture
- Fatigue and Wear

Extractive Metallurgy (W. W. Minkler, TIMET, U.S.A)

Specification and Test Methods (H. Kusamichi Kobe Steel, Ltd., Japan)

Fabrication Methods I (G. H. Gessinger, Brown Boveri & Co., Ltd., Switzerland; W. Knorr, Friendrich Krupp GmbH, F. R. Germany

- Melting and Casting
- Powder Metallurgy and Composites

Fabrication Methods II (D. W. Becker, Kohler Co., U.S.A.; W. A. Baeslack III, Air Force Materials Laboratory, U.S.A.; and R. W. Messler, U.S.A.)

- Welding and Brazing
- Metalworking

Corrosion and Oxidation (G. Beranger, Universite de Technologie de Compiegne, France)

- Corrosion and Hydrogen Absorption
- Oxidation and Oxidation Mechanisms

Phase Stability and Phase Equilibria (V. V. Tetyukhin, All-Union Institute of Aviation Materials, U.S.S.R.) Additionally, a special session with ten panelists was held on the Application of Titanium in Electric Power Stations.

For further details concerning publication of the Proceedings of the Fourth International Conference on Titanium, please contact:

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FOURTH INTERNATIONAL WORKSHOP ON RARE EARTH-COBALT PERMANENT MAGNETS AND THEIR APPLICATIONS AT HAKONE

Frederick Rothwarf

(Editor's note. A previous report on this meeting, listing only papers and their authors, was published in this *Bulletin*, Vol. 4, No. 2, (1979). The proceedings of this meeting are available at this office and specific ones can be sent to those who request them).

INTRODUCTION

The Workshop was attended by nearly 200 people (of whom only about 10% were Americans). These were of very diverse backgrounds and included representatives of the rare earth refining industry, applications engineers, physicians and fundamental materials scientists. This mixture of talents led to an interesting cross-fertilization that does not occur at the usual scientific meetings which tend to be more restricted in scope. Forty-six papers were presented at the twelve successive sessions which addressed the following topics (the number of sessions devoted to a given topic are in parentheses):

- electrical applications (2),
- medical applications (2),
- magnetic bearings and other mechanical devices (1),
- magnetic properties (1),
- magnetic after effect (1),
- structures and coercivity (1),
- permanent magnets (3),
- resources and refining of rare earth elements (1).

The published proceedings containing all but three of the papers on the program were available at registration.

APPLICATIONS

Professor K. J. Strnat, University of Dayton, the discoverer of the rare earth permanent magnets (REPM), gave the opening plenary address in which he reviewed the history of the field and presented a summary of the latest device applications, material developments, and future projections. This extensive overview nicely set the tone for the more detailed presentations that followed. He pointed out that, while the initial uses around 1965 of $SmCo_5$ magnets were limited to replacing expensive platinum cobalt magnets (which then sold for $3500 per kilogram) in military traveling tubes (TWT) and in specialized aerospace applications, the list of their present uses is rapidly growing The outline of the present applications given by Professor Strnat is quite impressive. It is shown in Appendix 1 with a few modifications to give the reader the present scope of REPM-based devices:

Many of the device papers at the Workshop expanded upon the applications listed in Appendix 1 and demonstrated that REPM can achieve a significantly smaller device size for a given performance, simpler design with fewer parts, and advantages in machining and assembly which yield savings in production. In most designs the REPM have replaced electromagnets, Alnico magnets and in some cases even ferrites. As energy costs increase, designers of motors and of systems which traditionally use large electromagnets are now finding that operating expenses can now be significantly reduced by the increased efficiency offered by employing permanent-magnet fields Rare earth magnets frequently offer the most energy-efficient design.

The most extensive development work in using the REPM has been done for motors and generators where the significant advantages that have resulted include the possibility of novel machine geometries, improved cooling, smaller volume and weight, greater design flexibility and simplicity, and enhanced reliability. Several papers addressed the questions of new motor/generator designs.

Microwave tubes built with REPM are outstanding examples of how the whole-system redesign approach can result in better, smaller, and cheaper end products even though Alnico or ferrite magnets are replaced by the more expensive REPM materials. Three papers discussed such new backward wave tube, magnetron and TWT designs Of particular interest was the fine paper by H. T. Soong and L. J. Kwang of the Southwest Research Institute of Applied Magnetics, Mienyang, Szchuan, Peoples Republic of China, on the design of O-type backward wave tubes for use at K band This was the first indication that the Chinese have a well-developed rare earth magnet research and design effort in progress Dr. Soong indicated that these tubes were now in mass production but refused to say for what application or where the tubes were being made. In this tube, $(Sm\text{-}Pr)Co_5$ magnets having an energy product of 20 MGOe were being used in a well-designed step-type focusing system to produce a uniform axial field of 1400 Oe along a length of about 6 5 cm over a diameter of 2.8 cm. The ripple was less than 30 Oe along the axis The magnetic circuit produced very low external leakage fields so that the tubes could be operated near magnetically sensitive instruments without any serious problems.

Two papers reported on the unique Japanese TWT and magnetron designs with REPM developed by the Toshiba and Hitachi companies. By incorporating the REPM inside the tube vacuum space, Toshiba has achieved a significant state-of-the-art improvement in their 2M166 magnetron for microwave ovens It has resulted in a tube having less than half the weight of the conventional tube used in a 600-W oven. The size of the tube was also reduced to nearly half the volume of the previous tube which employed ferrite. The weight of REPM used is only about 20 grams and represents less than 5% of the magnetron weight. Hitachi reported similar results.

A dramatic example of how the unique properties of high anisotropy, coercivity and energy products in the REPM permit radically new designs was given in the paper "A New Generation of Samarium-Cobalt Quadrupole Magnets for Particle Beam Focusing Application" by R. F. Holsinger of New England Nuclear and K Halbach of Lawrence Berkeley Laboratory. A new class of permanent magnet quadrupole lenses for beam focusing in proton linear accelerators has been invented based upon the $SmCo_5$ material. An optimized lens of simple design consists of 16 uniformly magnetized $SmCo_5$ wedges of varying magnetization directions and contains no iron poles. Very high field gradients and pole-tip fields of about 10 kG have been achieved. The structure has only one-sixth the weight of a conventional electromagnetic lens of equivalent performance and, of course, consumes no power. The evolution of this work has been particularly satisfying to me, since Dr. K. Halbach credits me with sparking this new idea during a talk that I gave at the Third International Workshop on Rare Earth-Cobalt Permanent Magnets and Their Applications in 1978 at San Diego In that talk and later conversations, I had pointed out that more use should be made of a relatively obscure idea originated by W. Neugebauer, who cleverly used the antisotropy of REPM materials for "guiding" flux around magnetic structures, thereby minimizing stray flux and enhancing the useful field

Another group of devices made possible with the advent of REPM are large magnetic bearings Before the advent of rare earth magnets the only bearings of this type in production were for watt-hour meters and a few clocks These used magnets in repulsion for axial support of rotor weight Since Earnshaw's theorem shows that complete three-dimensional stability cannot be attained in a bearing by means of permanent magnets alone, at least one degree of freedom always requires another bearing type such as a mechanical contact, an air cushion or an active electromagnetic system. The various papers presented detailed mathematical analyses of different bearing designs. Passive radial and axial PM bearings were described where repulsive or attractive forces (or both) are utilized Mainly passive REPM bearings are now used in high-speed spinning turbines and ultra-centrifuges for isotope separation Many servoed, partly or fully active, electromagnetic bearing systems are now in development using Sm-Co magnets as crucial components Most of these systems are for space applications Other terrestrial applications being studied include large energy storage flywheels and high-speed rotating electrical machinery, turbines, compressors, etc Such bearings reduce friction, eliminate wear and the need for lubrication and cooling. However, Professor Strnat pointed out that, since these new bearings compete with the accepted technologies of oil and gas-pressure bearing and depend on unique concepts and materials, their widespread acceptance and use will probably be very slow

Two sessions were devoted to various medical applications that employ REPM These included various dental prosthetic devices, techniques for measuring blood flow electromagnetically, and various cytological studies of the effects of magnetic fields on the growth of normal and tumor cells No definite cytotoxic effects of $SmCo_5$ or its magnetic field were noted, i e , neither inhibition of cell growth or morphological changes of the I L strain of cells studied were noted. No chromosomal aberrations over the acceptable upper limit were noted These findings support the adaptability and lack of cytotoxicity of $SmCo_5$ magents to the human body. They also showed a preference for using $SmCo_5$ magnets plated with Cr for various implantation applications, e g , for fixing dentures to gums. Initial inhibitory effects on the growth of several standard strains of tumor cells were noted on exposure to a field of 6 kOe but the effects diminished with succeeding subcultivations The mitotic activity was inhibited in the magnetic field and reached the minimum value 3-4 hours after removal of the cells from the field and recovered almost completely after 24 hours. Further research on these effects were recommended.

In private conversations with Mr. T. E Soung of the Peoples Republic of China, I was told of a new magnetic acupuncture technique which employs rotating $SmCo_5$ magnets applied in the vicinity of the conventional acupuncture points. This method does away with the need for inserting needles at the various points. Mr. Soung gave me a copy of a publication in Chinese which describes work done during the period from 1973-1975. Success is claimed with such varied conditions a high blood pressure, bronchitis, asthma, skin problems, heart disease, and vertigo.

MATERIALS

The latter half of the conference dealt with the various REPM materials, their fabrication and properties. Generally two types of magnets are distinguished by their production methods and physical characteristics. There are the sintered magnets and polymer-bonded (matrix) magnets. All sintered types (1-5 or 2-17, Sm, Ce, Pr or mischmetal-based) are hard and brittle and must be shaped by grinding or machining with diamond tools. They have fair electrical and thermal conductivities with good temperature/time stabilities for many applications. Polymer-bonded powder magnets made from the same alloys are also presently available. However, these offer less magnetic flux, poorer stability and lower maximum useful temperature (50-100°C) than their sintered counterparts. However, they can be pressed to size, easily machined or cut, are not brittle, and can even be made flexible or soft at the price of lower magnetic flux. Electrically and thermally they range from poor conductors to poor insulators. Their use is restricted to applications where ease of shaping and handling is more important than high energy, use is near room temperature and stability is not critical.

Certain topics or papers stand out as being of particular interest. These dealt with the questions of mechanical stability, the effect of oxygen content on coercivity, the effect of Ti, V and H_f substituents on the coercivity, and energy product of 2-17 compounds, new heat-resistant bonded magnets, and new composite reinforced RE-Co permanent magnets. These will now be discussed briefly in turn.

During several private discussions the need was emphasized for good data on, and approaches for, improving the mechanical properties of the 1-5 and 2-17 type magnets so as to minimize losses due to fracture in handling or heat treatment. Very little work has been done on this topic in the West or in Japan. The only two papers which touched on this subject were both from the People's Republic of China.

The temperature dependence of the lattice constants of the compounds $CeCo_5$, $Ce(CoCu)_5$ and $Ce(CoCuFe)_5$ were reported for the temperature range 25 C° to 600°C in the paper "Thermal Expansion Anomalies of the Compounds RCo_5" by Y C Yang, W. W Ho and C. Lin of Beijing University. $CeCo_5$ shows an Invar-type thermal expansion anomaly along the c-axis at the Curie temperature, T_c, i.e., a sharp increase in the slope of the C-axis lattice constant vs temperature curve occurs on heating above T_c No such discontinuity is seen for the a-axis lattice constant which shows a linear temperature dependence over the whole range. This anomaly is considerably reduced on the partial substitution of Co atoms by Cu atoms. Neutron diffraction studies of the compounds $Y(CoCu)_5$ show that the Cu atoms preferentially substitute on the 2c-site The reduction in the thermal expansion anomaly with Cu substitution is explained in terms of the Cu atoms acting to cut off very effectively the exchange interaction of the Co-Co atomic pairs along the c-axis.

"The Anisotropic Thermal Expansion and the Fracture of Radially Oriented Toroid Specimens of the Rare-Earth-Cobalt Permanent Magnets" by T D Sun, J H Fhu and D. W. Wan of the Research Institute of Iron and Steel, Beijing, dealt extensively with the results of a study of the fracture mechanism of radially oriented sintered $SmCo_5$ toroids It showed that the strong anisotropy of the thermal expansion controls the fracturing of the radial toroid after sintering. A detailed analysis in terms of the anisotropic values of the thermal expansion coefficients, moduli of elasticity, tensile strength and Poisson coefficients led to an expression for the critical degree of particle orientation with the c-axis along radial direction The parameter used to describe this orientation was $(\cos^2\theta)^{1/2}$, where θ denotes the angle between the c-axis of a crystallite and the radial direction along which it lies Both the calculation and experiment show that the critical degree of the orientation, $(\cos^2\theta)^{1/2}_{crit}$, should not exceed 0 7 Experimentally it was shown that the thermal expansion anisotropy could be decreased by employing a partial substitution of Cu for Co and a shift in composition toward the cobalt-rich (2-17 phase) region of the phase diagram They found that the compositions $Sm(Co_{0.80}Cu_{0.14}Fe_{0.06})_7$ and $Sm(Co_{0.87}Cu_{0.13})_8$ are almost completely isotropic and are ideal materials for making high performance, radially oriented toroids. The cause of the thermal expansion anisotropy in $SmCo_5$ was fully discussed in terms of exchange interactions between the various cobalt sites and their dependence on the various Co-Co lattice spacings. It was shown how the preferential substitution of Cu atoms on Co 2c-sites could explain the effective decrease in this anisotropy.

After the session which dealt with the effects on coercivity of the various secondary phases in the 1-5 and 2-17 compounds, prolonged discussion took place concerning the effect of oxygen in these materials. The role of oxygen in these magnets is not very clear and has been controversial for some time. It seems to be present in the form of islands of samarium oxide Sm_2O_3. C. Merget and M. Velicescu of the Goldschmidt Co , Essen, West Germany, indicated that their magneto-optical Kerr effect and microprobe studies showed these inclusions occur as separate particles of 2-3 μm size evenly distributed on the surface of the sample. The oxide particles are thought to be dead spaces that do not have any effect on the coercivity, though they lower the remanence and energy product. The oxide is now thought to be also present as the fine, submicron dispersion that would be required to produce the domain wall pinning needed to enhance the coercivity, but no one has been able to test this speculation definitively Strnat felt that if the oxide were present as a fine dispersion of precipitates, it probably has a concentration less than the 4,000 to 5,000 ppm that M. Ishigaki and A. Higuchi of Sumitomo Special Metals Co., Japan, have previously claimed yield on optimum intrinsic coercivity in $SmCo_5$. However, in any case, Strnat thought that it is indeed a finely dispersed precipitate of some kind whether oxide of carbide that contributes to the high coercivity of $SmCo_5$ or Sm-mischmetal Co_5-based magnets

The question arose as to whether a very high purity $SmCo_5$ magnet would still have a high coercivity. No one seemed to know. Strnat thought not. He doubted the possibility of achieving less than 200 ppm of oxygen on a commercial scale of production. Dr. K. V. S. Narashimhan of Colt Industries, Pittsburgh, expressed the opinion that one would indeed be able to achieve high coercivity $SmCo_5$ magnets with low oxygen content. He reported on efforts at Colt to produce low-oxygen content magnets under an Air Force manufacturing methods technology contract They have achieved magnets with energy products greater than 20 MGOe and with oxygen concentration less than 2,000 ppm, as compared to industrial standard magnets which usually have greater than 6,000 ppm of oxygen. The Colt results contradicted the Sumitomo results mentioned above. No one in the audience seemed to have any good ideas for resolving the discrepancy.

Recent problems with the international cobalt supply have limited the allocations to magnet manufacturers and have caused unprecedented increases in the price of cobalt Since the rare earth magnets make much more effective use of the contained cobalt than do Alnicos, many of the Workshop talks on materials were concerned with the possibilities within the family of REPM of enhancing the magnetic energy per unit weight of cobalt above that obtainable even with $SmCo_5$. Recent Japanese and Swiss work has indicated that energy product, $(BH)_{max}$, in excess of 30 MGOe can be achieved. In the Sm_2Co_{17} and other 2-17 alloys, it is possible to substitute substantial amounts of Fe, Cu and also some Mn or Cr for a part of the Co and still be able to maintain or improve the performance of the material Therefore, these factors have stimulated renewed materials development of the Sm_2Co_{17}-based alloys, particularly by the Japanese

Several papers were presented which dealt with the effects of various substituents such as Ti, Zr or Hf on the coercivity and energy products of REPM. Papers by Inomata's group at the Toshiba Research and Development Center of Kawasaki in collaboration with Gato, Sakurai and Ito of Tohoku University dealt with "Magnetic Characteristics of $Ce(Co, Cu, Fe, Ti)_{6.4}$ Magnets " One paper by Yoneyama, Fukuno and Ojima of TDK Electronics Co., Ichikawa, Chiba, was entitled "Magnetic Properties and Structures of $Sm_2(Co, Cu, Fe, Zr)_{17}$ type Magnets," while another paper by Nezu, Tokunaga and Igarashi of Hitachi Metals Ltd , at Kumagaya, Saitama was "$Sm_2(Co, Fe, Cu)_{17}$ Permanent Magnet Alloys with the Additive Element Hf." In all of these alloys the IV-A substituent acts to enchance the coercivity and thus the energy product. The exact mechanism for doing so is obscure It was speculated that the presence of carbon in all of these compounds, as reported by Herget and Velicescu points to the existence of a fine dispersion of the various IV-A carbines in the respective alloys Such a dispersion might act as the source of the domain wall pinning defects needed to enhance the coercivity In various discussions, it was generally agreed that it would be important for future work to determine whether the Ti, V, or Hf substituents go into solution and thus act on the crystal fields or whether they form the fine dispersion of oxides or carbines, referred to above, and act as pinning sites

The important papers on resin-bonded were presented "A Heat-Resistant R-Co Bonded Magnet," by Suzuki, Yamane, and Kamine of the Mitsubishi Steel Mfg Co , Tokyo, and Hasegawa, Hamano, and Yajima of Tohoku University, Oarai, Ibaraki, dealt with a new type of heat resistant polymer-bonded R-Co magnet manufactured by using $SmCo_5$ powder and a newly developed borosiloxane-based polymer that featured excellent thermal stability in air up to 400°C. Measurements of magnetic properties of the bonded magnet yielded B_r = 6.3 kB, ${}_iH_c$ = 6.4 kOe and $(BH)_{max}$ = 9.3 MGOe. Also, the irreversible loss in spontaneous magnetization at $-B/H = 3$ was 2.5% for a 150°C heat-treated sample and 5.5% for a sample treated at 200°C Such characteristics are comparable to that of sintered $SmCo_5$ magnets. These excellent magnetic properties were confirmed to be due to:

- the heat resistance of the polymer,
- the high content of the polymer in the magnet, over 2 wt%,
- the high density, over 6 5 g/cc, of the magnet,
- the high coercivity of the $SmCo_5$ powder.

The long term stability of this material has not been determined. These magnets are not yet commercially available.

A paper by Shimoda, Kasai, and Teraishi of the Suwa Seikosha Co., Suwa, Nagano, described a "New Resin-Bonded Sm-Co Magnet Having High Energy Product," in which Sm_2Co_{17}-based magnet material was used with an epoxy resin. High coercive force was obtained using a composition of $Sm(Co_{0.672}Cu_{0.08}Fe_{0.22}Zr_{0.028})$ where Z varied from 8.35 to 9.0. An ${}_iH_c$ over 20 kOe was found for Z = 8.35 with appropriate heat treatment. Initial magnetization of these magnets showed that the magnetization was controlled by domain wall-pinning. Since the ${}_iH_c$ did not depend on the particle size used, high density magnets (ρ = 7.1 g/cm³) were made by combining large particles with small ones to reduce the void content. The magnetic properties were B_r = 8.5 kG, ${}_bH_c$ = 6.8 kOe and $(BH)_{max}$ = 17.3 MGOe. These were exceptional results for a bonded magnet. Two very sophisticated production processes were described. In one method called "the whole die press forming method," the powders (magnet and resin) are packed, pressed and pulled out from the die in a single process. The resin is then cured to obtain the final magnet product. This method makes it possible to manufacture the magnets with excellent dimensional accuracy and requires only half the cost of the conventional process.

Another paper that aroused considerable interest was entitled "Composite Reinforced RE-Co Permanent Magnets," by P. H. Draper of Les Fabriques d'Assortiments Reunies, Le Locle, Switzerland. Draper described a new class of precipitation-hardened RE-Co permanent magnet alloys with improved mechanical properties which minimize the problems associated with the brittleness of currently available RE-Co materials. The microstructure of this class of materials consists of a small volume fraction of ductile cobalt dendrites within a cobalt-copper-rare earth matrix and is produced by directioned solidification. A pilot plant operation is presently being developed. Metallurgically, the current alloys being commercially developed consist of three phases:

- The Co dendrite phase, occupying 10 volume %, and incorporating a large fraction of the other transition metal-elements.
- The 2-17 type phase, saturated with Sm and Cu, and occupying about 70% of the volume.
- The 1-5 type phase containing about 20% Cu.

The material is not fully in equilibrium at low temperatures according to the ternary phase diagram However, the Co phase, once formed, shows no measurable tendency to redissolve The fracture energy of this material is five times greater than that of sintered $SmCo_5$ magnets. Consequently, the material exhibits greater machinability and can be turned and/or drilled using conventional hard metal techniques. Better surface quality and more precise dimensions can be obtained, particularly for small work pieces. The material is also less susceptible to thermal shock. The magnetic properties are modest compared to $SmCo_5$. Those presently attainable are Br = 8 0 kG, ${}_iH_c$ = 5 5 kOe and $(BH)_{max}$ = 14 0 MGOe The major limitation results from the fabrication method which controls the form of the raw magnet material a cylindrical bar, some tens of cms in length and about one cm in diameter with a unique magnetization axis along the length of the bar Other cast forms are also possible, using the techniques of directed solidification, but considerable development work will be required.

A special session was held on the Fundamental Problems of Rare Earth-Cobalt Magnet Materials. It was chaired by Professor Wallace of the University of Pittsburgh He opened the session with a lengthy commentary of his own thoughts on the matter that I feel are worth preserving in this report, along with some of the replies that his thoughts prompted. Wallace felt that "the fundamental scientific base on wh[illegible] this technology is resting is very, very narrow indeed" Paraphrasing Winston Churchill, he said, "Never has so la[illegible] a technology owed so much to such a small amount of basic science," and pointed out that the whole technology is now based on the characteristics of just the three materials

(Mischmetal)Co_5, $SmCo_5$ and Sm_2Co_{17}. He reviewed the properties required of a good permanent magnet material, namely: "a good remanence, a sufficiently high Curie temperature, and the most subtle feature of a strong magnetic anisotropy. The alignment of the magnetic moments is maintained by the anisotropy energy, e g , the crystal field interaction that operates between the several Co sublattices and the rare earth or SM sublattice. The Co sublattice anisotropy in $SmCo_5$ is not very strong. It is not significant in producing good permanent magnet behavior. One needs the rare earth anisotropy, which makes the major contribution to the magnet anisotropy. What is wrong with the cobalt anistropy? Why doesn't it do the job? The anisotropy of Co in YCo_5 and $LaCo_5$ is quite high and is presumably due to the Co alone, but you can't take advantage of it there to attain good magnets The anisotropy field of Sm in $SmCo_5$ on the other hand is quite high and you can take advantage of it. It is quite clear that the issue of the anisotropy that is developed out of the Co sublattices is very poorly understood." Wallace felt that the most revealing treatment of the problem has been done by Dr. Inomata at the Toshiba Research Center, "but he keeps his conclusions and his calculations locked up in a laboratory report written in Japanese because he is not confident that this really should be exposed yet to the full public. However, the issue of why there is the strong cobalt anisotropy sometimes and why it differs from the single ion anisotropy exhibited by the rare earth sublattice is not at all well understood."

Professor Wallace emphasized the need for detailed band structure calculations before we will have adequate fundamental understanding of the based materials. We do not understand the role of d-band sublattices in these materials.

Wallace also pointed out that all the compounds are chemically dirty as well as being brittle. In fact, it is known that other substances become ductile when adequately cleaned up He speculated that a very clean $SmCo_5$ material might be ductile and more amenable to simple manufacturing processes. Since these materials have a strong affinity for oxygen and carbon, the adverse mechanical properties may arise as a result of being so dirty. Wallace wondered about the properties that really clean compounds, i.e., semiconductor-grade $SmCo_5$ and Sm_2Co_{17} compounds, might have.

Professor Strnat replied that Joe Becker of GE, years ago showed that small single crystals of YCO_5, prepared carefully, attained a high coercivity and a $(BH)_{max}$ of 28 MGOe, so that the Co anisotropy is not absolutely worthless. But it is somewhat more difficult to put to practical use than the rare earth crystalline anisotropy. Dr. Rashidi of Hitachi Magnetics said· "it would be nice to come up with a clean alloy, but it does not make a good magnet. All you would have would be a clean alloy." He indicated Hitachi has determined that, in order to maintain repeatability of magnet properties a certain amount of oxygen is an absolute necessity. Lack of oxygen gives a shiny alloy, but the alloy does not make good magnets.

Strnat agreed with Rashidi and further said that higher coercivities might be attained in pure alloys from a scatter-disorder mechanism similar to that observed by Oesterreicher. Those coercivities seem to exist only at low temperatures, but not at room temperatures. The high coercivity in any of the practical magnets seems to rely on some form of dirt, e.g., another intermetallic compound precipitated out, some type of stacking fault structure, and/or oxide or carbide precipitates. Possibly the zirconium or titanium carbides, that Dr. Valicescu found, are important agents in causing the magnetic hardening. In the end you may need the dirt for the practical magnets.

Wallace, changing the subject, asked "Wouldn't it be nice not to be geared to use the Co? Wouldn't it be nice to have a $SmFe_5$ alloy for example, that would behave substantially like $SmCo_5$? A very interesting fundamental question is why don't the $REFe_5$ compounds form." Of course $ThFe_5$ does form, suggesting the possibility that there are some electronic factors involved. Wallace and one of his associates are now doing a band structure calculation for $SmFe_5$ to see if by examination of the electronic band structure they might be able to ascertain what parameters might be manipulated to bring this material into existence.

Professor Wallace also felt that there was a lack of a concerted effort on the part of the rare earth magnet community to explore other options. He pointed out that "Jeitsko, formerly of DuPont and now at the University of Giessen, recently reported on a number of rare earth iron phosphors, which are 2-19 compounds and are materials which are potentially uniaxial. Their magnetic properties have not been investigated." He also noted that "the initial work on the structure of the 2-17 compounds was done many years ago in the Soviet Union by Gladisheskii, who has continued to synthesize many potentially interesting new magnetic compounds. Their magnetic properties have also not been studied, even though they might be of interest for application After all, the 1-5 compounds date back to the work of Novotony in Austria forty or fifty years ago. The 2-17's are also very old compounds. There are lots of things like these 2-19's or the compounds that Gladisheskii is providing or a number of other compounds that warrant investigation as potential permanent magnet materials " It seemed to Wallace that the basic science that needed doing, collateral to the present technological effort, should be a strong follow-up on these new compounds. When Wallace asked for further suggestions for new materials from the audience, there were none.

FUTURE MEETINGS

At this time tentative preparations are being made for a 5th Workshop in the USA and a 7th in Europe, while Professor Ho Wen-Wang of Peking University has received permission from his government to hold the 7th meeting in China during 1982.

APPENDIX I

REVIEW OF PRESENT RARE EARTH PERMANENT MAGNET APPLICATIONS

A. ELECTROMECHANICAL DEVICES

1. *Electric Motors*: Types – DC (commutator and brushless), synchronous, induction start/sync. run, rotary and linear; continuous, torque, stepping. Geometries – PM stator (conventional or ironless armature), PM rotor; radial or axial field (disc motor). Applications – Watch and clock drives, aerospace gyros, momentum wheels, textile spinning turbines, servomotors, machine tool drives, (jet engine starter, electric vehicle propulsion, automotive accessory motors and starters under development).

2. *Electric Generators*: Types – Brushless DC motor/generators, exciters, alternators, multi-phase sync. machines, pulse generators. Geometries – PM rotor, radial or axial field; stator winding with or without iron. Applications – Tachometers, satellite energy storage wheels, excitation of large sync. turbogenerators, aircraft turbine ignition, (400 Hz main aircraft generator/starter in development).

3 *Electromechanical Actuators*: Linear – Computer printers; magnetic head, laser mirror, recorder pen positioners Rotary – (Aircraft control surface (fin) actuators in development).

4. *Sound/Ultrasound Technology*: Microphones, earphones, loudspeakers, vibration sensors, phonograph pickup.

5. *Measuring Instruments*: Moving-coil meters (core magnet), moving magnet instruments.

6. *Electrical Switches*: Reed switches, snap-action relays, thermostats, eddy-current motor overspeed switch, Hall-effect switches (microswitch, automotive ignition).

7. *Accelerometers/Gyroscopes*: Military and commercial navigational/guidance systems.

B. MECHANICAL FORCE AND TORQUE DEVICES

1. *Couplings and Brakes*: Synchronous torque couplers, eddy current and hysteresis brakes, rotary-to-linear motion converter.

2 *Magnetic Bearings and Suspensions*: Passive – Textile spinning turbines, ultra-centrifuges, watt-hour meters, record-player tonearm support, adjustable magnetic spring, (repulsive vehicle support). Partly active servoed system – gyros, satellite momentum and energy wheels, laser beam scanner (Turbo-molecular pumps, electromagnetic/electrodynamic vehicle levitation in development).

3 *Holding and Lifting* Special purpose holding (elec. switching by flux displacement in development) See also D. 1, 2.

4. *Biomedical Devices* Catheters, eyelid muscle assist, stoma seal, dental prostheses (Implantable pumps and valves, head support harness in development.)

C. MICROWAVE AND ION BEAM TECHNOLOGY

1. *Microwave Tubes*: TWT PPM focusing, klystrons, magnetrons, crossed-field amplifiers and backward-wave oscillators.

2. *Waveguide Devices*. Ferrite biasing in nonreciprocal waveguides, circulators etc., YIG resonance filters.

3. *Particle Accelerators* PM quadrupole lenses.

4. *Mass Spectrometer*· Deflecting magnet in spacecraft instrument.

D. MISCELLANEOUS APPLICATIONS

1. *Magnetic Locks*· Key with magnets.

2. *Magnetic Jewelry*: Necklaces, clasps, earrings.

3. *Electronic Chokes*: Steady bias field.

4. *Magnetic Bubble Memory*: (Thin-film REPM for bias field under development.)

RARE EARTH – COBALT PERMANENT MAGNETS: VISITS TO JAPANESE LABORATORIES

Frederick Rothwarf

(Editor's Note: Following the "Fourth International Workshop on Rare Earth-cobalt Permanent Magnets and their Applications at Hakone, "Dr Rothwarf visited Japanese laboratories, together with Professors Karl Strnat and A. E. Ray of the University of Dayton.)

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Dr. T. Hori, Chief Engineer, Magnet Div., Narita Factory
Dr. T. Honeyama, Research Scientist

TDK were quite interested in trying to understand where the zirconium was going in their 30 MGOe, REC-30 alloy that is currently in production Even though they have achieved a significant enhancement of the energy product, they do not understand exactly why it is happening. They asked us our opinion of the role the zirconium was playing and where it was going in the crystal structure Professor Al Ray thought that the zirconium was probably occupying cobalt sites. His long experience with metallurgical processing led him to believe that the zirconium atom and all the other transition metal atoms, such as Ti, Nb, Ta, Hf, that have been tried will not go into a site where they rattle around. They tend to go into sites where they have to squeeze themselves in or can just barely make it. Therefore, he feels that it is into the Co-sites in the 1-5 compounds that these substituents go. In the 2-17 compounds, they would go into only the "dumbbell" Co-sites. He feels that the rare earth sites are too large for the transition metal atoms to enter. However, he is not absolutely certain that this is in fact occurring Such atoms might also be going into a second phase. In that connection, I raised the question of Takahashi's work During the Hakone meeting, I had met Professor M. Takahashi of the Applied Physics Department of the Engineering Faculty, Tohoku University at Sendai. He privately described his very interesting work on dilute solutions of various transition elements and rare earths in pure cobalt. He had found some dramatic effects due to such substituents They led to remarkable enhancements in the anisotropy energies when the dilute cobalt alloys were subjected to magnetic annealing. Apparently the effects are caused by a very finely dispersed second phase in pure cobalt I wondered whether such a cobalt-rich dispersion might be present and act as the pinning centers in some of the alloys we were considering. Al Ray felt strongly that I was correct in assuming that there must be a finely dispersed phase present in these materials. He based his opinion on observations of large supercooling during differential thermal analysis experiments on the melts of 2-17 and 1-5 materials. The supercooling produces a super-saturated cobalt solution. The subsequent spontaneous heating, Ray felt, is indicative of a massive nucleation of a very finely dispersed second phase similar to that which I had intuitively suggested. We asked the Japanese to look at the effects of a magnetic anneal on these materials to see if there is any enhancement of the anisotropy or coercivity that might indicate the presence of this finely dispersed cobalt precipitate They indicated they would try this experiment Ray also suggested that they put a thermocouple in their melts to see if they observe the DTA curve characteristic of the massive supercooling effect.

The laboratory was very impressive Everything was clean and neat They have a central data acquisition/computer facility for the online processing of experiments from all parts of the laboratory Each room in the laboratory has a data acquisition/processing terminal which is connected to the computer They had a complete materials characterization facility x-ray diffraction, scanning and transmission electron microscopes, ESCA, and microprobe analysis. The completeness of the characterization facilities puts most of the United States government and industrial facilities to shame They had a very fine Edwards ion-milling apparatus for thinning down their specimens for transmission studies I was very impressed by the fact that this relatively small industrial company has had the vision to invest so heavily in, and fully staff, such an analytical, characterization, magnetics measurements and data acquisition/processing operation to provide rapid feed back to their materials development people

Their magnetics laboratory was equipped with a large 20-kOe electromagnet where they do their magnetization and anisotropy field measurements. They have to extrapolate to high magnetic fields to estimate their anisotropy fields and intrinsic coercivity values They use a rather simple arrangement to obtain high temperature magnetization data with their TEOL vibrating sample magnetometer. A quartz tube with a bifilar nichrome winding that is insulated with asbestos sheeting permits measurements to 1,000°C No water cooling is used.

We were told about the new TDK plant at Narita which opened in September 1978, and now employs about 100 people. It has 9,000 m^2 for magnet production and 7,500 m^2 for product assembly, e g , RE-G necklaces, home drinking water deionizers and vaporizers. The RE-Co magnet production capacity is 10 tons/month. Presently, production is 3 tons/month, (40%, 1-5 material; 60% 2-17 material). The magnet types are (1) $SmCo_5$, made from (a) the Goldschmidt reduction-diffusion processed powder called TEOMAG and (b) the TDK cast alloy Sm 60/Co 40, (2) Mischmetal Co_5, and (3) the REC-24 (parallel pressed) and REC-30 (transversely pressed) Sm_2Co_{17}-based magnets. According to Professor Strnat, who subsequently visited the Narita plant, it was an all new, highly automated facility with the latest processing and machining equipment.

ELECTROTECHNICAL LABORATORY (Tanashi Branch, (since then moved to Tsukuba), 1-1-4, Sakura-mura, Umezono, Niihari-Gun, Ibaraki 305)

Dr. Tachiro Tsushima, Chief, Magnetic Materials Section
Dr. Tsugio Shibata, Senior Researcher
Dr. Takashi Horigome, Chief, Energy Systems Section
Dr. S Ihava, Senior Researcher

The Electrotechnical Laboratory (ETL) is the largest national research organization specializing in electricity and electronics in Japan. Since its establishment in 1891, ETL has greatly contributed to the progress of science and technology by serving as a nucleus for R&D activities in Japan ETL became affiliated with the Agency of Industrial Science and Technology in 1948. Since then, many reorganizations and expansions have occurred in order to cope with the needs for rapid technological innovation. During fiscal year 1978, ETL had a staff of 768, of whom 573 were research personnel The FY78 budget was about $32,000,000. At present, ETL is primarily involved with the following four R&D areas: solid physics and materials, information processing, energy, as well as standards and measurements. ETL is also taking technical leadership in performing three national R&D programs. one is for MHD generation (1966-1982), another is for pattern information processing (1971-1980), and the last is the so-called "Sunshine Project" (1974-2000), in which ETL is engaged in R&D of solar and hydrogen energy technologies. ETL is also establishing fundamental technologies to serve as the basis for future national programs on space and ocean engineering.

The magnetic materials section had a permanent staff of eleven scientists, eight of whom were Ph D.'s, and one secretary It had no technicians but had a temporary staff of eight, consisting of one person from industry, three graduate students doing their Ph.D. theses at ETL, and four undergraduate students Dr. Tsushima indicated that it was quite common for ETL to supplement its staff with people from industry or the universities. The fields being studied by the section were amorphous magnetic metals, rare earth-cobalt magnets, amorphous thin films, magnetic semiconductors, thin film bubbles, magneto-optic studies, the liquid phase epitaxy and dynamic behavior of garnets This is quite a range of materials. They had an impressive amount of equipment, all of it seemed to be functional Some of it was dated, but not too much so. Their laboratories were not as well equipped for analytical and characterization studies as the TDK laboratory. They have a unique high-temperature arc-imaging single crystal growth furnace A high intensity halogen lamp is at one focus of a gold-plated elliptical cavity, while the single crystal is grown at the other focus by slowly pulling a suitable seed crystal from the feed material being melted at a temperature of about 1500°C by the concentrated radiant energy They have been growing a variety of rare earth orthoferrites such as $REFeO_3$, where RE = Er or Sm They have also been studying the iron borates, Fe_3BO_6, with cobalt and titanium substituents for some of the iron. As one alters the dopant concentration in this material, either a spin reorientation transition or a change from antiferromagnetic to weakly ferromagnetic behavior occurs on increasing the temperature

Dr. Tsushima's major interest has been spin reorientation systems such as $NdCo_5$ and the rare earth orthoferrites. Such systems change from one magnetically ordered state to another magnetically ordered state when thermodynamical parameters such as temperature, magnetic field, or pressure are changed. As one increases temperature, the hexagonal $NdCo_5$ system changes from a basal plane anisotropy to an axial anisotropy, while the $REFeO_3$ materials show the reorientation of the spontaneous moments between the a-axis and the c-axis of a distorted perovskite structure He has studied these transitions by means of Faraday rotation, magnetization, and specific heat.

Tsushima has found some interesting applications for these materials; it turns out many of the $RECo_5$-type compounds exhibit such spin reorientation phase changes over a well-defined temperature interval, $\Delta T = (T_{sr2} - T_{sr1})$ A large discontinuity in specific heat usually occurs at the upper limit, T_{sr2}, of the temperature interval over which spin reorientation occurs. In particular, the $Dy_{1-x}Nd_xCo_5$ ternary system has such a transition whose characteristic temperatures T_{sr2} vary with its Nd concentration from 285K for $NdCo_5$ to 367K for $DyCo_5$. Tsushima makes use of the transition region, an interval of about 40K, where the material becomes magnetically soft, whereas above or below this interval the material is hard. By heating with a high intensity lamp or concentrated sunlight, a rod of this material, which is placed in a magnetic circuit containing a RECo permanent magnet bias and a transformer coil wound on one of the soft iron legs of the circuit, he obtains a device for converting thermal into electrical energy by suitably chopping the light The $Dy_{1-x}Nd_xCo_5$ alloy is alternately changed from a soft to a hard magnetic state by the thermal impulses. The alloy thus modulates the magnetic flux linking the circuit as it changes from a high to a low permeability state. The device essentially makes use of the change in alloy specific heat that occurs with spin reorientation. This specific heat change represents about 10% of the total specific heat of the sample. It is about 10^7 ergs/cm^3 However, this total energy is not realized because only a surface heating is obtained at the chopping frequencies employed Thus it is useful to use thin sheets of material having as large an area as possible. A chopping frequency of about 30 to 40 rpm is used.

This effect has also been used in a photo-motor developed by Dr. Tsushima's brother at the Nihon Broadcasting Corporation, NHK. Elements consisting of orthoferrite sheets are fixed on the perimeter of a quartz wheel The edge of this wheel is biased in the gradient produced by two sets of canted ferrite magnets located near the circumference of the wheel at either end of a diameter. The quartz disc is free to rotate on its axis and is caused to do so when chopped light is focused on the orthoferrite plates on its edge. Speeds up to 30 rpm have been achieved. Stacks of such discs on a given axis can be used to obtain a higher power output. This is a very novel device. A demonstration has been running in a department store window in Tokyo for several months with no difficulties. Rare earth cobalt biasing magnets could be used with $Dy_{1-x}Nd_xCo_5$ single crystal materials to obtain greater torque output from such a photo-motor. Some of this work has been written up in IEEE *MAG 13*, 1158 (1977) A paper was also presented at the Hakone Workshop on this work. Dr. Tsushima showed us a short film demonstrating these devices.

Dr. T. Shibata and Mr. T. Katayama, with the help of Mr. M. Katsu of the Brother Industrial Co , have been studying the coercivity in $Sm(Ce_{1-x}TM_x)_5$ sintered magnets where TM = Fe, Mn, Cr A dramatic maximum in the coercivity, ${}_iH_c$, vs composition curves was observed at x = 0.1 in the Sm-rich compounds, $SmCo_{4.35}TM_x$ for each of the substituents. Sharply peaked ${}_iH_c$ vs annealing temperature curves were also found with optimum temperature in the range 850-900°C They felt that the coercivity mechanism in these materials was the same as that for $SmCo_5$, namely, reverse domain nucleation. The details for this work were given in Paper XI-5 at the Hakone Workshop

The orthoferrites are also being studied for use as optical modulators A thin single crystal is biased in a Helmholtz coil set. When helium-neon red laser light impinges on the crystal after passing through a polarizer, it is transmitted through the analyzer when no magnetic field is applied. In a field the plane of polarization is rotated so that no light is transmitted through the analyzer. Fields of only 10 to 30 Oe are used to modulate the light Good contrast is produced To date only modulation frequencies up to 1 kHz have been used, but the high domain wall velocities indicate that the orthoferrites should be capable of being modulated to frequencies as high as 10 MHz This is an order of magnitude better than can be achieved in the garnets

The most interesting work that I saw was on a time-resolved observation system for the high-speed contracting motion of bubble domains in real time, being done by Dr. M. Hirano A TV system was used for recording the motion of bubble domains generated by the incidence onto LPE-garnet films of laser pulses produced by a Q-switched YAG Nd^{3+} laser that puts out 10 μsec pulses These cause domain stripes to move across the field of view One can get the velocities of these stripes from the pictures that they take They had to modify the electronics of the TV system so that, instead of getting 16 or 32 frames per second, they choose one particular frame to record magnetically each second They have found that the contracting velocities in YIG-coated films have an asymmetry with respect to the sense of the in-plane field. This asymmetry can be attributed to the YIG layer being on one side of the films. The details of some of these experiments were published in J. Appl. Phys. *49*, 1909 (1978).

The magnetics section is also doing work on magnetic semiconductors. Large (∿ 1-cm-diameter) single crystals of $CdCr_2Se_4$ have been grown using a traveling-zone, flux-melt technique. These are huge compared to the best size previously available, which were cubes about 2 mm on a side. There is no practical use yet foreseen for this work. Various magneto-optical and resonant Raman scattering studies are being done to elucidate the electronic structure of this spinel-type ferromagnetic semiconductor. At the moment, it is just a basic research study.

Silicon substrates are being used to grow their Gd-Co-Mo amorphous films for bubble memory work. Of course, the single crystal Si substrates are easy to obtain; they have a good thermal match to the GdCoMo material and are much cheaper than the GGG, gadolinium gallium garnet, commonly employed as a substrate.

TOSHIBA R&D CENTER, Toshiba-cho 1-banchi, Komukai, Saiwai-ku, Kawasaki-city 210

Dr. Shu Chiba, Manager, Metals and Ceramics Laboratory
Mr. Naoyuki Sori, Deputy Manager, Metal Engineering Section
Dr. Koichiro Inomata, Senior Researcher
Mr. H. Hoxie, Researcher
Mr. Teruo Oshima, Researcher

Dr. Chiba showed us a brief, closed circuit TV film of a few of the projects being worked on at the Toshiba R&D Center. This work included e-beam lithography, using both positive and negative resists with resolutions better than 1 um; lithium tantalate SAW devices; the technology of fabricating NbTi superconducting wire; an *in situ* method for producing Nb_3Sn superconducting films; projects concerning VLSI; and superconducting levitated high speed transportation systems. Toshiba, Hitachi, Mitsubishi, Matsushita are all collaborating with Japan National Railway to produce a superconducting levitated train. Such a joint effort would be impossible in the U.S.A. because of our anti-trust laws. Synchronous pulsed coils in the track supply the energy for levitation and propulsion. Superconducting magnets are located on the train cars. The train becomes levitated at speeds above 100 km/hr. Current designs call for a maximum speed of 500 km/hr. We were told that Toshiba has about 60,000 employees, of whom 1,500 work at the R&D Center.

After the overview by Dr. Chiba, we met with Dr. Inomata and his associates to discuss the Toshiba REPM effort and products. These include high-fidelity loudspeakers and earphones, stepping motors for clocks, radially anisotropic "TORSOREX$_{TM}$" magnets for motors and generators, magnetrons and large generators. They showed us new, very thin loudspeaker designs that were now in production. They were quite proud of a new REPM-based magnetron tube for their microwave cookers. This tube replaces one that used a ferrite biasing magnet. The new tube has an output of 1 kW as compared to the 0.75 kW of the old design. It also had about two-thirds the weight and volume of the old tube, which had occupied a cubic volume 4″ on a side. All of their magnets employ Ti rather than Zr as the substituent used to enhance the coercivity They are making cost-effective cerium-based magnets with an energy product close to 14 MGOe. They showed us anisotropy constant data on the system $Ce(Co_{0.851-x}Cu_{0.136}Fe_xTi_{0.013})_{6.4}$. A maximum occurs at $X \simeq 0.13$ with a value of $K = 2.5 \times 10^7$ erg/cm^3. We were given a large, as-cast sample having a $(BH)_{max}$ = 13.6 MGOe and a composition $Ce(Co_{0.742}Cu_{0.14}Fe_{0.107}Ti_{0.011})_{6.32}$. Their samples are induction-melted under an argon atmosphere in magnesia crucibles and cast into an iron mold. The as-cast ingot is then ground into powder without a homogenizing heat treatment. The powder is subsequently aligned with a pulsed magnetic field, pressed into the desired shape, and sintered at 1100°C in an argon atmosphere for an hour. It is then given a controlled air quench with rapid cooling rates of about 200 to 300°C/sec, followed by a one-hour anneal at 400°C to develop the intrinsic coercivity $_iH_c$. $_iH_c$ remains at about 5.5 kOe, independent of annealing temperatures, in the range 300-700°C above 700°C, it drops rapidly to below 1 kOe They indicated that this material has a 1 7 composition in the grains and 1 5 in the grain boundaries. Dr J. Livingston of G E. has analyzed the microstructure of the Toshiba Ce-based material and published the results in IEEE Trans, Magnetics, MAG-*10*, 313 (1974). Their higher energy product samarium cobalt-based alloys are close to the 1·7 composition and also contain Ti as the coercivity enhancing substituent along with iron and copper. Dr. Inomata also gave me samples of their TOSOREX$_{TM}$, TS-22 Sm-Co material, which is rated for continuous use to 200°C. At 230°C, the material shows a loss of only 5% in its remanence Inomata was interested in having us measure the anisotropy fields in their materials.

Having overseen the development of commercially useful magnet materials, Dr. Inomata has now been assigned to the development of amorphous metal, high permeability magnetic materials This is unfortunate from the point of view of fostering a basic understanding of the REPM materials, since he had been doing some very important NMR studies concerning the contribution of the various cobalt sites to the magnetization and anisotropy of these materials As was mentioned above, Professor Wallace feels that the most revealing theoretical treatment of the contributions to the anisotropy by the different Co sublattices has been made by Dr. Inomata, who has not yet felt confident enough to publish his results. Inomata gave me a sample of the new amorphous magnetic material that his group has developed to replace permalloys in recording heads. It has the composition $(Co_{0.88}Fe_{0.06}Ni_{0.03}Nb_{0.03})_{75}Si_{10}B_{15}$ The Ni and Nb substituents are used to enhance the mechanical stability of the material. I promised to check on what effect the absorption of hydrogen might have on the magnetic properties of this material, since Dr Tauber and I have found that other Metglass-type materials can have their magnetic properties significantly degraded or enhanced by the presence of hydrogen

NATIONAL RESEARCH INSTITUTE FOR METALS, 3-12, Nekameguro 2-chome, Meguroku, Tokyo 153

Professor – Dr. Toru Araki, Director
Dr. H. Maeda
Dr. H. Moma
Dr. Y. Sasaki
Dr. K. Hoshimoto

Professor Araki has had a distinguished career dealing with the metallurgy of steel. He is currently President of the Iron and Steel Institute of Japan. The Institute of Metals publishes its own journal in English, "Transactions of the National Institute of Metals." A subscription can be obtained by writing to Professor Araki. The Institute is also participating in the national "Sunshine" and "Moonlight" projects. The first is an effort to develop new energy sources, while the second is to extend and promote energy conservation methods There is a major effort on the development of various corrosion and stress resistant steel alloys for the shipping industry. The improvement of welding techniques for steels and the tensile testing of welds are also areas given great emphasis. Other areas of interest are the rare earth-cobalt permanent magnets, metal hydrides for hydrogen storage applications, and amorphous metals. We were told that the Institute will be moving within a year or two to modern facilities in the new "Science City", Tsukuba, about 80 km north of Tokyo. A new university is to be located there as well as many of the national laboratories

Dr. Maeda took us on a tour of the institute facilities which were housed in a large complex of buildings about 60 years old. Everything seemed to be well-maintained. We were shown some huge tensile testing-machines, about two-stories high used for testing the single pass welds in two or three-inch thick steel plate used for building the supertankers Also quite impressive was a floor filled with row on row of high-temperature stress corrosion furnaces used for the evaluation of steels and other high-temperature alloys to be used in the eventual construction of breeder reactors. These computer-controlled and -monitored furnaces were part of a five-year, 15-million-dollar testing program to determine the at-temperature stress corrosion properties of many alloys They feel that only data taken under actual-use conditions for long periods of time are valid. They do not believe that the accelerated testing and statistical modeling used by the Americans have been valid approaches, as evidenced by the large amount of down-time in our reactors due to the failure of steam lines. There were 1100 such furnaces in use on one floor and 750 on another as part of this extensive testing program. These tests are under the direction of Dr Moma and involve following the interaction between creep and fatigue, especially thermal fatigue, and employ the alternate low-frequency application of compressive and tensile stress at high temperatures

Dr Maeda told us briefly about the coercivity calculations that he has done for the highly anisotropic $R(Co_{1-x}M_x)_5$ alloys where R = Y, Ce, Pr, Sm and M = Cu, Ni. He used a simple discrete-spin configuration model for a domain wall in the presence of planar short-range fluctuations of the exchange interaction and anisotropy, which strongly depends on fluctuations in the distribution of non-magnetic elements. He has found that, by using a reasonable magnitude for short range fluctuations, he can predict coercive fields of the same order as those measured.

Dr. Maeda introduced us to Dr. Y. Sasaki, who has developed a fine facility for studying the hydriding of magnesium-based alloys for use in automotive applications He has a Kahn balance arrangement, such as Dr A Tauber is building at ET&DL, for studying hydriding kinetics at various temperatures for pressures below one atmosphere The pressure below one atmosphere is regulated by the thermal decomposition of ZrH_2 in a temperature-controlled reservoir He also has a high pressure apparatus for doing similar studies in pressures to 70 atmospheres This unique apparatus was built under contract by Japanese industry and employs a hydrogen cylinder with a mechanical compressor. Sasaki has been studying hydriding in the single phase Mg_2Ni alloy and the polyphase material $Mg_{0.60}Ti_{0.15}Ni_{0.20}Fe_{0.05}$ Some of Dr Sasaki's work on these metal hydrides is being sponsored by the Daimler-Benz Company of West Germany in connection with their attempt to develop a hydrogen-fueled atomobile.

We were also introduced to Dr. I. Hoshimoto, who has been studying the hardness and tensile strength of amorphous metals of the system $(Fe_xNi_{1-x})_{78}Si_{10}B_{12}$. His work correlating the microstructure of these materials as seen in electron micrographs with their hardness and tensile strength was scheduled for publication in *Scripta Metallurgica*. He was nice enough to give me samples of his alloys so that we might check on their capacity to absorb hydrogen and any consequent changes in their magnetic properties

SHIN-ETSU CHEMICAL INDUSTRY CO., LTD., 6-1, Ohtemachi 2-chome, Chiyoda-ku, Tokyo 100

Dr. Y. Tawara
Mr. M. Honshima
Mr. T. Chino
Mr. K. Ohashi
Mr. C. Nakazawa, Director

The Shin-Etsu plant at Takefu employs about 600 people. They are engaged in rare earth oxide reduction rare earth separation, and the production of rare earth-cobalt magnets. They also produce polypropylene thin films for capacitors and single crystal silicon for the semiconductor industry. Their subsidiary, Shin-Etsu Hannotai, was formerly a partner with Dow Chemical and today is one of the world's big three producers of single crystal silicon (along with Wacker and Monsanto). Shin-Etsu also produces fused quarts for semiconductor processing furnaces, and high quality quartz for optical fibers. The quartz products are made at a plant in Esobe. Silicone oils and rubber are also produced at the Takefu location. After giving us an overview of the Shin-Etsu business, Mr. Nakagawa left us to detailed technical discussions with Dr. Tawara and his rare earth magnet group. These talks were very open, furnishing us many technical details which they have not yet published in the open literature. Even the subsequent trip through their manufacturing facility was quite open. They answered all technical questions most freely. This frankness was due to the friendship between Professor Strnat and Dr. Tawara, who had spent nearly a year as a visiting scientist in Strnat's laboratory at the University of Dayton a few years ago.

The raw material for their magnet and rare earth production is obtained from Europe as a concentrate from xenotime ores. They obtain Y, Sm, Gd and a small amount of Eu. They use an ionic separation and solvent extraction method to obtain the rare earth metals. Since their own production of samarium is insufficient for their magnet production needs, they buy Sm metal and samarium oxide where they can in the world markets. They make their magnet alloys both by a direct alloying of the metals and through a reduction-diffusion processing of the oxides. They are presently making both Ce-based and Sm-based magnets. They are using about 15 tons/year each of Sm and Ce. The cheaper Ce magnets are used in watches and clocks. In fact, the Japanese are exporting watch movements to Europe, even to Switzerland and France. There is a much bigger demand for the Sm- than for the Ce-based magnets. However, since Rhone-Poulenc, a major rare-earth supplier, has warned about the limited world supply of Sm, the Shin-Etsu people are trying to conserve Sm by combining it with Ce while still trying to maintain a relatively high energy product magnet Thus, while the compound $CeCo_5$ has only a $(BH)_{max}$ of 15 MGOe, the compound $Sm_{0.5}Ce_{0.5}Ce_5$ has a $(BH)_{max}$ of 20 MGOe With proprietary substituents into this latter material, the Shin-Etsu people expected to be in production with a 22-MGOe magnet in about three months.

They are also developing Sm_2Co_{17}-type compounds having energy products close to 30 MGOe Since the TDK patents for such materials are based on materials having $7.2 < Z < 8.5$ in the formula $Sm(Co, Fe, Cu, Zr)_z$, the Shin Etsu group is developing material with $Z \simeq 6.2$. They are also using Zr substituents to develop the coercivity. However, by using the lower transition metal concentrations they avoid conflict with the TDK patent position

Dr. Tawara and his people still are uncertain as to how the Zr is enhancing the coercivities in these materials I told them about my discussions with Takehashi and about my speculation that internal magnetic fields may be imposing order on a fine dispersion of ZrCo precipitates They had no comments on this idea We also discussed the idea of a ZrC precipitate contributing to the coercivity as put forth at the Hakone Workshop by Drs Greinacher and Velicescu of the Goldschmidt Co. Dr Tawara said that it is difficult to keep the carbon level down in pure Sm or Sm_2O_3, since some contamination is inevitable from the milling with hexane or toluene. Greinacher of Goldschmidt claims there is always some carbon contamination in the starting oxide materials. Tawara said that, while CO_2 goes off during the arc melting process so that only 0 002% carbon is left, this concentration goes up about tenfold after milling since milling brings in CO_2 from the air. Thus, the Shin-Etsu people specify a 0 02% carbon concentration in their powder materials. Some further addition may take place in the pressed magnet bodies due to the stearate-type mold release employed, which enters the magnet during the sintering process.

Dr. Tawara pointed out that Shin-Etsu has been using Mn to enhance the coercivity of their magnets for some time, even though they have never published or said anything publicly before. They have studied the system $Sm(Co_{0.80}Fe_{0.05-y}Cu_{0.15}Mn_y)_{6.85}$ and found they got fairly good magnets with a $(BH)_{max}$ of 23 MGOe with y = 0.03 The intrinsic coercivity $_IH_C$ is found to increase fairly uniformly with Mn concentration even up to Y = 0.05, i.e., with no Fe present. While a quench gives higher $_IH_C$, they usually age their material at 750°C for about 45 minutes and then give it a slow furnace cool to 400°C with a final cool also in an argon atmosphere to room temperature. The slow cooling gives sound magnets with uniform properties. One of their present commercial magnets has a energy product of 21 MGOe with y = 0.025 and is made with a slow cool-down. Another magnet compound, their S-25 material, has a $(BH)_{max}$ = 25 MGOe with Z = 6.8. It contains Ti as well as Mn and has the formula $Sm(Co_{0.702}Fe_{0.015}Cu_{0.11}Mn_{0.03}Ti_{0.008})_{6.8}$. The Ti is used as a replacement for Zr. The combination of the Mn with the Ti helps Shin-Etsu get around the Toshiba and TDK patents.

We were taken for a tour of the magnet measurement and production facilities. Their measurement facility includes an electromagnet capable of achieving about 18 kOe. They have an automated B-H Analyzer with an analog-to-digital tape data storage system, which used an Intel 8080 16-kbit RAM. The system, designed and built by the Shin-Etsu Engineering Co., uses two tape cassettes – one for data storage and the other for programming. The system is used as a permeameter with the magnet poles screwed down flush to the magnet face, so that demagnetization effects are eliminated. A search coil surrounds the magnet and its output is fed to the integrating flux meter assembly.

A pulsed-field magnetizer (2,500 V, 2,000 μF), capable of supplying a 15,000 A pulse with a 1 ms rise time and a broad 1 ms peak, was used for the one-shot magnetization of a variety of magnet configurations. Several different coil jigs were available to supply axial, radial, or transverse magnetizations. The peak pulsed magnet field achieved depended upon the jig coil configuration, but usually was about 25 kOe. They also had a 50 Hz demagnetization arrangement for the 2-17 type materials because of their relatively low coercivities. All production magnets are pulse magnetized, tested, and then demagnetized before shipment to the customers.

Sintering and heat treatment of magnets is done in three large, 12-ft-long furnaces which are heated with carbon resistance elements. An argon atmosphere is used in all the operations. Each furnace has three chambers held at the different temperatures for a batch processing, semicontinuous operation. They also have several small test furnaces, 8 ft long, also with three chambers separately controlled. Green pressed magnet material is first preheated at 400°C and then sintered at 1200°C. After sintering, samples are moved through gate valves with fork-lift type transfer devices to a fan-cooled chamber. The S-25 material is given a subsequent treatment in an aging furnace, 8 ft long, which has four chambers at temperatures of 750°C, 650°C, 550°C and 440°C. This furnace has tantalum windings and also uses an argon atmosphere. A long push-rod is used through a vacuum seal to push the molybdenum sample boats, having inconel edges to prevent warping, to the various heat treatment zones.

Automated multiple punch-presses with pulse electromagnets associated with each die were used to align and press the magnet powders. Various dies were available to make bars, rings, and radial arc segments. Two types of presses were available, either with the aligning field perpendicular to the pressing direction or parallel to it. The aligning fields used were about 10 kOe. For axial (parallel) pressing, the pressure used was about 1 ton/cm², while for transverse pressing it was 0.6 ton/cm². The latter was the method for making their large standard blocks (1 X 3 X 6 cm) The green density achieved was 54% of the theoretical value, while the final density after sintering was 99.8% The die lubricant was stearic acid.

The factory is working 24 hours per day, seven days a week. Four full-time production teams have been trained and they rotate their shifts from week to week. Shin-Etsu is currently selling all the magnets and magnet powder they can make.

Both attritor and jet milling processes are used to make the magnet feel powders. The jet milling is more convenient for the Sm-based magnets, while the attritor is more useful for the Ce-based material. At the moment, they have one large unit of each type and are in the process of acquiring another jet mill. These units start with coarse 20-mesh powder obtained from another plant in Takefu. The jet mill can process material at the rate of 150 kg/day to produce the final 3 μm powder. The attritors and jet mills are made by Japanese companies. The jet mill was made by the Japan Pneumatic Co., while the attritor was supplied by the Mitsui Mill and Attritor Co. The powder is sized by a Fischer unit. Six storage chambers are used for drying the powder by means of aspirator pumps. The powdered material is stored in sealed chambers under dry nitrogen gas. Final powders of various materials are stored in color coded cans in a fireproof cinder block room.

The final mechanical finishing of the magnets was done in a large modern automated machine shop. They had twelve automated cutting machines with sets of parallel diamond impregnated blades of thickness from 0.6-0.8 mm. These machines were used to square-up the ends of bar magnets. The cutting edges were on the inside surface of the blades. Automated surface grinders with magnetic chucks were used to attain given thickness specifications. Inside/outside grinders for segmented-arc, concentric torque coupler assemblies for large, seal-less chemical pumps were also in use. Tight eccentricity tolerances are required for the torque couplers. Shin-Etsu is manufacturing torque couplers having two sets of eight magnets facing each other on concentric rings. The I.D. of the outer ring is 95 mm, while the O.D. of the inner ring is 75 mm. The magnet dimensions are 5.5 X 5.5 X 1.0 cm and they are made of the Ce-based Rarenet H material. The device delivers a torque of 180 kg-cm. A similar coupler, employing the Sm-based Rarenet S-22 material, delivers a torque of 300 kg-cm. Dr. Tawara indicated that larger torque couplers with a capacity of 3,000 kg-cm are being developed in Germany for autoclave chemical processing. The machine shop works only two shifts for 16 hours a day and handles about one-half of the machining load. The rest is contracted with outside Japanese companies. Incidentally, great care is also taken to salvage and recycle all of the scrap metal resulting from the magnet machining operations.

At this time Shin-Etsu is using about 50% of its magnet production/sintering capacity. They are now producing 3 tons per month, which is about 50% Ce-based and 50% Sm-based. While the magnet business was profitable last year, it is *not* currently profitable because of the dramatic rise in cobalt prices (nearly sixfold from $6.85 to $40 per pound) that has taken place since the invasion of Zaire in May 1978. The competition (TDK, Toshiba, Hitachi, Sumitomo, Mitsubishi) is also keeping magnet prices down. Market prices are still going down in Japan. Shin-Etsu is carefully thinking about recycling processes to salvage solid material from breakage in handling the brittle magnets, machining, and cutting sludges from water grinding operations. They are also seriously considering producing plastic bonded magnets, which would not be so brittle and could be pressed to any size and shape.

SUMITOMO SPECIAL METALS CO. LTD., 22, Kitahama 5-chome, Higashi-ku, Osaka, Osaka 541

Dr. A. Higuchi
Mr. Y. Matsuura
Mr. N. Ishigaki
Mr. H. Yamamoto
Mr. Aoyagi, Director, Manager of Yamazaki Works

Sumitomo Special Metals Co is making ferrite magnets at a rate in excess of 1,000 tons/month. They are second only to TDK and are aiming to achieve a production of 1,500 tons/month at their Kyushu plant. They presently produce about one third of the Japanese ferrite magnet output. A new fully automated plant was also due to go into production in July 1979 at Yabu in Hyogo Prefecture. They hope to achieve, with this plant on-line, an ultimate total production of 3,000 to 4,000 tons/month. Sumitomo also makes cast and sintered nickel based alloys, permalloys, glass-sealing Kovars, FeCrCo permanent magnet alloys, and 45% of the Japanese Alnico production. Their Alnico production rate was currently 200 tons/month with a capacity for 500 tons/month. They are also producing the RE cobalt permanent magnets as well as such soft alloys as the permandurs and amorphous metals. They are using hot isostatic pressing methods for making soft ferrite materials for recording heads needed in computer, audio and video applications. Sumitomo is not involved in making any microwave or millimeter wave devices as such

Their nickel alloys are produced at the Suita Works, which has facilities for hot and cold rolling Layers containing three to five sheets can be bonded simultaneously by cold welding in one pass Such composites replace pure Ni in various anode applications, especially in power transmitting tubes for the television industry The same facility produces Nichrome and Alumel as well as the low expansion coefficient Invar and Superinvar alloys

The Yamazaki Works makes a variety of Alnico and RE cobalt magnets for torque couplers, TWT's, magnetic separators, and toner arms for Xerox type photocopiers. They also make a sheet floating device using permanent magnets for handling large steel sheets in various manufacturing plants They also use microcomputers such as the Hewlett-Packard 9820A to design magnetic circuits for their customers. In fact, an automated hysteresograph, which uses an HP9820A, was designed by Dr. Higuchi and is being marketed by the YPH (Yokagawa-Hewlett-Packard) Co. in Japan

In the manufacture of the RECo magnets, facilities for x-ray fluorescence and wet chemical analysis are used for quality control. In particular the hydrogen, oxygen, carbon, and sulfur content of the starting powders are monitored.

Mr. H. Yamamoto is working with (Mischmetal) Co_5 magnets trying to optimize the substitution of Fe for Co and Sm for MM. He finds that the coercivity critically depends upon the milling and sintering procedures. $SmFe_5$ and $MMFe_5$ have not been observed; only the 2-7 and 2-17 phases seem to form Al Ray commented that the systems RE $Co_{5-x}Fe_x$ form only for X = 0, when RE = Sm and for $X \leq 1.5$-2 for RE = Y or Ce. Namiki in Tokyo claims to have made a reasonable $(Sm_{1-x}Y_x)_2Co_{17}$ magnet where X = 0.1. They have licensed Sumitomo to make such magnets.

MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD. – MATERIALS RESEARCH LABORATORY, 1006, Momma, Momma, Osaka 571

Mr. Y. Sakamoto
Dr. T. Kubo, Head of the Magnetics Division

Matsushita has developed a unique magnet material, manganese aluminum carbon, MnA C, that has an energy product of 6.0 MGOe and a coercivity of about 2.8 kOe. This standard alloy, now being sold commercially, has a nominal composition of 70 w/o Mn, 295 w/o Aℓ, 0.5 w/o C. However, an energy product of 8.0 MGOe has been achieved in the laboratory with a small amount of Ni substituent. Sakamoto indicated that the material had a relatively low Curie temperature near 300°C. The irreversible loss in magnetization is about 5-7% on cycling the material from room temperature to 100°C and back for an operating point at $(BH)_{max}$. No policy on licensing agreements had been established as of the time of our visit. Matsushita is the only producer of the material. They have a fully automated pilot plant on-line, which produces several hundred extruded cylinders per month. A hot extrusion process at 700°C is used to achieve an 85% reduction in cross-section and to impart a uniaxial anisotropy to the material Starting 80 mm ϕ billets are cast in magnesia crucibles in air at about 1450°C. Very little oxidation occurs, but about 1% hydrogen is detected, since the starting electrolytic Mn contains hydrogen. Long bars about 31 mm in diameter are produced, since Matsushita is using discs 31 mm ϕ X 6 mm as speaker magnets. Several thousand test speakers have been produced for a new line of very thin (∿10 cm) Panasonic wallet-sized AM-FM receivers.

The extruded MnAℓC material is very hard to machine and requires tungsten carbide tools as well as a special heat treatment. The material cannot be soldered to directly with lead-tin solder, but the use of an electrolytic coating permits such soldering.

The pricing of the material is between that of the Alnicos 5 or 8 and the ferrites. It can replace Alnico 8 for small magnet applications. This is important in view of the high cobalt costs, which have driven up the prices of Alnicos

The Matsushita people showed us several prototypes of new products which will use these magnets These included

- A magnetic reed-switch security system.
- A reed-tuning fork assembly for clocks.
- An automotive engine speed tachometer.
- An 8-pole magnetic toner-roller magnetized along four equally spaced diameters for xerox-type photocopiers These 14 mm ϕ rollers replace 41 mm ϕ ferrite rollers. Here 2-MGOe isotropic magnets are used These are produced by control of the composition, conditions of extrusion, and heat treatment.
- A flat, 6-pole, disc-armature motor for an electric bicycle The MnAℓC replaces a ferrite used in a previous prototype and yields a 50% reduction in total motor weight and produces 1 5 times the torque The bicycle has a 20-km range and uses a lead-acid battery which can be recharged overnight It is currently being test marketed in the Osaka area

- A small 3″ speaker for the "Mister Thin" Panasonic radios mentioned above. For a 3″ speaker with comparable performance, the use of MnAℓC requires a magnet weighing only 23 g, while Alnico 5 and ferrite magnets would weigh 34 g and 48 g, respectively.
- Various electrical analog instrument meters.

THE ENVIRONMENTAL RESEARCH CENTER, UNIVERSITY OF TSUKUBA

H. J. Walker and Masao Inokuchi

INTRODUCTION

While planning for the transfer of Tokyo University from Tokyo to Tsukuba Science Center, the concept of establishing an Environmental Research Center (ERC) at the new site was formulated. The objective of the new center would be to facilitate the study of natural phenomena on and near the earth's surface, especially those phenomena related to geomorphology, hydrology, and meteorology. After plans were developed and approved, construction was begun in 1975 and is still continuing.

Located on the northwestern corner of what is now known as the University of Tsukuba, the Center occupies 67,000 m^2 of area on which is located a large flume, a meteorological observatory, an administration and research laboratory building, a temporary building with small flume and wave generating tank, and a workshop among other supporting buildings (Fig. 1).

The Center's staff includes the Director, Dr. Masao Inokuchi (coastal and fluvial geomorphology), who holds a joint appointment with the Institute of Geoscience, Dr. Kazuo Kotoda (hydrometeorology), Dr. Hiroshi Ikeda (geomorphology), Dr. Yugo Ono (periglacial geomorphology), and five technicians. This staff manages the Center, maintains its equipment, and organizes the research conducted at the Center. Although the bulk of the research at the Center is conducted by the permanent staff, the Center is also used by graduate and undergraduate students from several colleges at the University in thesis work and by other University faculty members.

FACILITIES

The Center is divided into two sections; a hydraulics section and a heat and water balance section. Its facilities were designed to promote the research of these two sections and center around a large flume and a heat and water balance experimental field.

The Large Flume

Experimental flumes have been used for decades at various research laboratories in the Netherlands, England, and the U.S.A. among many other countries. Most flumes have been small and all have certain inherent weaknesses. Prior to the construction of the flume at the ERC, specific objectives were established and detailed studies of the qualities of established flumes were examined. Among the objectives were·

- to simulate the changing inclination of natural stream beds,
- to simulate variations in textural proportions of bottom materials in natural beds,
- to have the flowing water in the flume sufficiently deep so that turbulence can be examined,
- to reduce the side friction of the flume to a minimum,
- to conduct long-period experiments without interrupting the sediment or water supply, and
- while achieving the above objectives, maintain a reasonable operating cost

The resultant flume, constructed in 1976 and 1977, is 4 m wide, 2 m deep, and 160 m long and completely housed (Fig 2). Although the original plans specified that it be constructed of concrete, soil tests at the building site showed that serious settling would likely occur Therefore, steel was used Because of size and weight and the great expense of providing a jacking system for changing inclination, it was decided to use a fixed bed with a slope of 1/100 In order to vary the inclination of the simulated river bed studied, gate systems at the end of the flume were added and allowed the changing of the slope for 0 to 1/50.

The 4 m width minimizes side effects and the 2 m depth allows the establishment of a relatively thick sedimentary bed (up to 1.6 m deep) when needed The pumping system can provide a maximum discharge of 1.5 t/sec which allows the development of deep flow.

The sieving and mixing system which can handle both sand and gravel was added in 1978. With this addition the flume can be operated with either straight sediment re-circulation or with a texture-controlled feed system. In the re-circulating system, sediment that has been deposited in the settling tank is recovered, weighed, and transported by conveyor belt to the head of the flume, where it is fed directly back into the flume. In the texture-controlled feed system, the sand and gravel (up to 25mm in diameter) is first transported to sieving and mixing equipment and, after the desired proportions of textural categories are obtained, fed into the flume. These systems when combined with the water circulating system permits continuous experiments over long periods of time.

The experiment-controlling and data-gathering systems were added in 1979. They include a control room that allows remote control of television cameras and other data gathering systems. There is an electric carriage with longitudinal and transverse capabilities, allowing the measurement of flow velocity, water depth, and bed characteristics. There is also an electric photographic carriage that is suspended from the ceiling. It runs automatically at speeds varying up to 1 m/sec and can be used to photograph flow and bed forms stereographically.

The Heat and Water Balance Experimental Field

Research on the heat and water balance is facilitated by a grass covered experimental field 160 m in diameter (over 20,000 m^2). At its center is a 30 m high meteorological observation tower. On the tower and in the field are a number of instruments including:

- sonic anemometer thermometers (at 30.5, 30.0, 12.4, and 1.6 m),
- resistance thermometers (at 30.0, 12.4, and 1.6 m),
- dew point thermometers (at 30.0, 12.4, and 1.6 m),
- resistance thermometers (at -2, -10, -50, and -100 cm),
- heat flux plates (at -2 and -50 cm),
- groundwater level gauges (as -2, -10, and -20 m),
- pyroheliometer,
- total hemispherical radiometer,
- net radiometer,
- weighing lysimeter,
- evaporation pan,
- rainfall intensity recorder,
- rain gauge, and
- discharge meter (for measuring runoff from the experimental field).

All of these instruments are tied into a terminal box that leads to a data recorder and eventually to a printout form.

In addition to the 30-m tower, there is also an 8-m observation pole. Psychrometers and 3-cup anemometers at heights of 0 5, 1 0, 2.0, 4.0, and 8 0 m provide data on wind velocity and wet and dry air temperatures. Periodic measurements are made of area and height of the grass growing in the experimental field.

The main purpose of this system is to acquire the long term basic data needed to aid in the understanding of the heat and water balance under natural conditions and to clarify the transfer processes of heat and water energy in and near the surface boundary layer.

Other Facilities

The Center's main building (725 m^2) serves both as an administrative and research building It has a number of offices and data acquisition, documentation, basic analysis, dark, and study rooms. The staff refers to this building as the "brains" of the Center, whereas the flume and the experimental field are the "muscles"

Because the Center is still under construction (see below), some of the research is presently conducted in temporary laboratories. One such laboratory houses a small flume (0.5 m wide, 1.0 m deep, 13 m long) and a two-dimensional wave generation tank (0.5 m wide, 0.7 m deep, 21 m long). The workshop (which contains a small trough for the the calibration of current meters) is also a temporary building.

Future Facilities

The addition of three additional laboratories has been approved. They include:

- a hydraulic laboratory (2,025 m^2) which will house several flumes capable of supporting large scale experiments,
- a soil mechanics and ground-water hydrology laboratory (1,120 m^2), and
- a water balance wind tunnel laboratory (608 m^2).

PRODUCTIVITY

The ERC has two publications: one, the *Bulletin of the Environmental Research Center*, which consists of articles stemming from research at the Center; the other, *Observational Data of Heat Balance and Water Balance*, which contains tables of data collected by the Center. Only one number of *Observational Data* has been published (issued in March 1980). It covers data collected over the 20-month period of August 1977 to March 1979.

The Bulletin is issued annually in March. To date, four numbers have appeared (1977-1980) and contain 31 research articles and some 20 other (usually short) items that describe techniques and equipment. The *Bulletin* is in Japanese; only the titles of articles are presented in English. Six examples of these articles include:

- K. Kotoda, "A method for estimating lake evaporation based on climatological data," (1977) No. 1: 53-65

This article deals with the method of estimating deep-lake evaporation. In the case of deep lakes, such as Lake Biwa (Japan's largest), Penman's formula is only partially applicable because it does not consider the effect of changes in heat storage. In this study, the wind parameter f(u) in the Dalton type evaporation formula

$$E_B = f(u)(e_s - e_a)$$

was estimated as

$$f(u) = 0.316\,u$$

by the use of the climatological data at Hikone meterological observatory The values of f(u) for Lake Biwa were found to be very close to the values obtained by Jacobs in 1942. A new evaporation formula which considers the effects of atmospheric stability was proposed and is

$$E_s = [0.13u(e_s - e_a)]/[1 + 0\ 375 \exp(-10.5s)]$$

where

$$S = (T_s - T_a)/u^2$$

- Y. Ono, "Pipkrakes as a periglacial process," (1979) No. 2. 47-55.

This paper summarizes the studies about pipkrakes in Japan and in the rest of the world About 70 articles are reviewed and criticized. Though the mechanism of the formation of pipkrakes has been well studied by physicists, their role as a periglacial process has not yet been clarified. The asymmetry of one valley in the Kanto Plain has been explained by the difference in pipkrake activity on valley slopes of different exposure However, actual measurements of the processes in this region have never been made. The accumulation of basic data concerning the geomorphic process of pipkrake development is badly needed.

– R. Kawamata, "On the two-dimensional beach transformation in the surf zone," (1978) No. 2. 9-15.

In this paper a model is presented that describes onshore-offshore sand transport and two-dimensional beach transformation in the surf zone. Equation 2 (below) reflects the conditions at the time net transport is in a state of equilibrium. Two important parameters controlling sand transport are the dimensionless fall-time parameter and bottom slope. Using these parameters, the direction of onshore-offshore transport and the beach profile in the surf zone are expressed as:

1. $<$ 0.3 (onshore transport, accretion profile)

2. $(H_0/L_0) \tan \beta/(w_s/gT) = 0.3 - 0.7$ (neutral; equilibrium profile)

3. $>$ 0.7 (offshore transport; erosive profile)

where w_s is the settling velocity of sand grains, T is the period of waves, H_0 is the wave height of deep-water waves, Lo is the wave length of deepwater waves, g is the acceleration of gravity, and β is the angle of the beach face.

– H. Ikeda, Y. Ono, K. Izumi, and R. Kawamata, "The speeds of solid grains, rolling along the smooth bed," (1979) No. 3: 7-15

The velocities of particles of various sizes and densities were examined in the 4-m-wide flume at different flow depths in order to determine the velocity of single spherical particles rolling on a smooth bed. As a result, the relative or slip velocity of particles (i.e., the difference between the speed of the fluid and of the particle), is not equal to the fall velocity of the particle in stillwater, but, instead, is proportional to the intensity of the viscous resistance on the particle. The viscous resistance is caused by the particle's revolution in the viscous fluid.

– Y. Matsukura, K. Izumi, T. Sasaki, and I. Takeda, "The diffusion of grains in the lee slope of aeolian dunes in Nakatajima, Shizuoka Prefecture," (1979) No. 3: 47-53.

Barchan-like dunes, with wavelength ranging from 20 m to 200 m and with heights ranging from 0.5 m to 10 m, are formed on the backshore (inside a beach ridge) in Enshunada beach, Central Japan. Wind velocity profiles and amount of sand drift were measured on these dunes. The amount of sand drift on the lee slope (slip face of the barchans), which was transported by saltation from the brink line, was trapped. The grain size distribution of the blown sand was determined. A good correlation between shear velocity and the amount of sand drift and/or the diffusion of the grains in the lee slope was found.

– Y. Sakura and I. Kaihotsu, "Observation of vertical movement of rainwater in the lysimeter," (1980) No. 4. 25-29.

The vertical water movement in the Center's lysimeter was investigated by the observation of changes in pressure head (tensiometer), water content (neutron scattering moisture meter), temperature (thermocouple), and groundwater discharge (flowmeter) during and after a rain in August 1979. The groundwater table was fixed at 160 cm beneath the ground surface.

The analysis of these observational data showed that vertical water movement is affected significantly by entrapped air and that the value of the soil water flux estimated from the change of soil temperature agrees well with that determined by measurement.

The titles of the articles summarized above are printed here as presented in the *Bulletin*. Because the *Bulletin* does not carry abstracts, the summaries above are modified from some provided by the authors of each article for this paper

Those readers interested in flumes may find useful the 33-page article entitled "The 4-meter-wide flume in the Environmental Research Center " Although in Japanese, it contains 60 photographs and drawings that illustrate nearly all aspects of the flume. It and any other information about EKC may be had by writing the Japanese author of this article at

The Environmental Research Center
University of Tsukuba
Ibaraki 305
Japan

The American author would like to take this opportunity to express his thanks to the staff of EKC for the many courtesies extended during his 9-month stay in Japan in 1979. Included was the use of a large office which greatly facilitated his own research.

FIGURES

Fig. 1. The Environmental Research Center.
- the large flume,
- the heat and water balance experimental field,
- the 30-m observation tower,
- the main building,
- a temporary laboratory,
- the workshop, and
- planned facilities
  - a hydraulics laboratory,
  - a soil mechanics and ground water gydrology laboratory,
  - a water balance wind tunnel laboratory.

Fig. 2. Internal view of flume during a bed configuration research project.

Fig. 3. The water and sediment circulating system of the flume.
- water reservoir,
- pumping equipment,
- high water tank,
- flume,
- gate system,
- settling tank,
- sediment recovery system,
- sediment weigher,
- sediment re-circulation conveyor,
- sieving and mixing system,
- sediment feeder, and
- underground piping system.

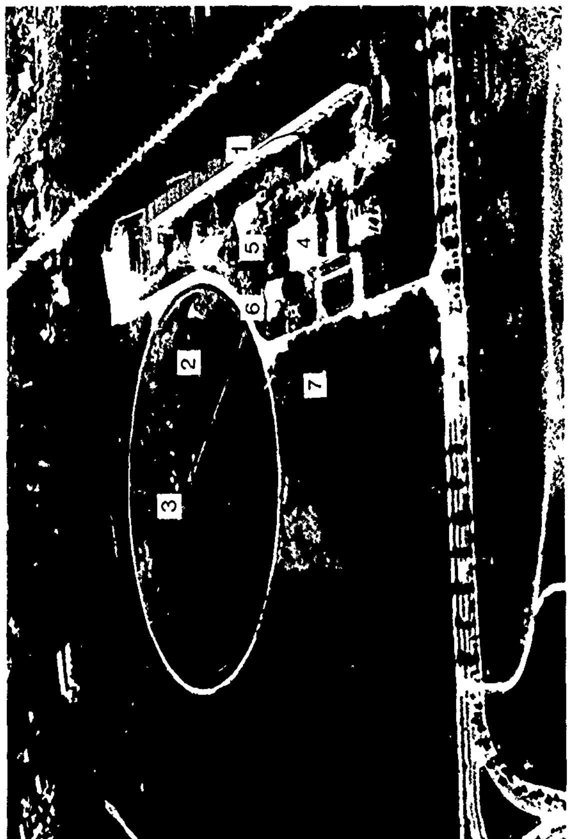

Figure 1.

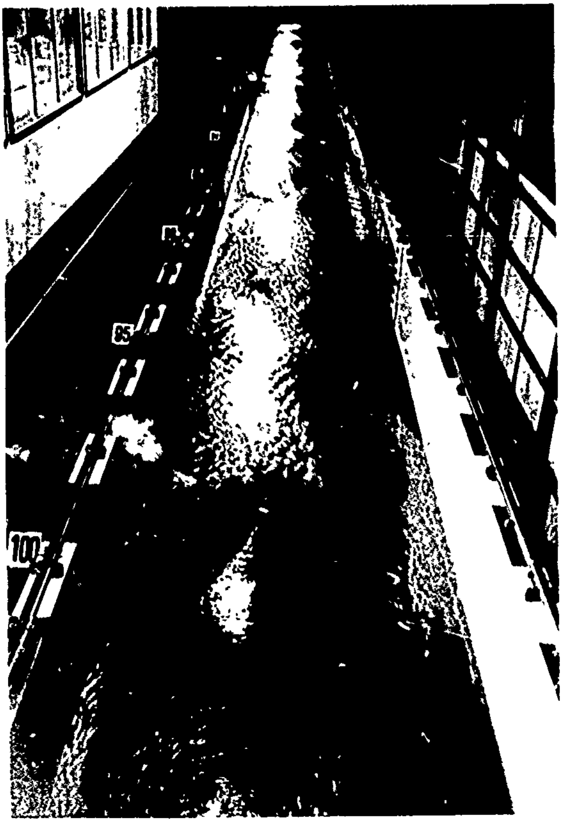

Figure 2

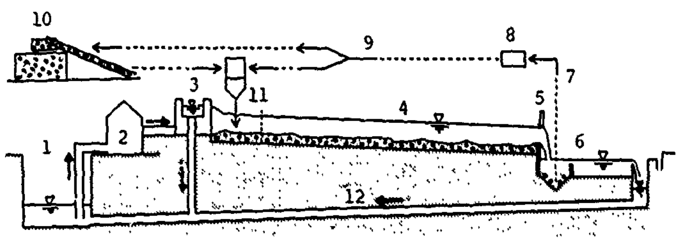

Figure 3.

WESTPAC WORKSHOP ON COASTAL TRANSPORT OF POLLUTANTS AND ANNUAL MEETING OF OCEANOGRAPHIC SOCIETY IN JAPAN

Takashi Ichiye

INTRODUCTION

A year and a half after my last visit [this *Bulletin* (S.B.), *3*(4), 67-71, (1978)], I had a chance to visit Japan again. This time my main purposes were to discuss with Japanese oceanographers the future cooperative study of the three straits into the Japan Sea, and also to attend the workshop sponsored by UNESCO on Coastal Transport of Pollutants (CTOP) for the WESTPAC (Western Pacific) Program, 27-31 March, in Tokyo. Since the annual meeting of the Oceanographical Society of Japan (OSJ) was to be held in Tokyo 5-9 April, I assumed that the first purpose would be achieved by attending this meeting and associated symposia.

WESTPAC WORKSHOP ON COASTAL TRANSPORT OF POLLUTANTS

The WESTPAC program seems to be a continuation of CSK (Cooperative Study of the Kuroshio and adjacent regions) which was started in the early sixties [Richards, this *Bulletin* *4*(2), 71-73 (1979)]. U.S. oceanographers have been inundated by so many acronyms in the seventies, the decade noted as IDOE, that they may not be concerned with one or two more like CSK or WESTPAC. However, for oceanographers of the CSK countries, particularly Japan, Korea, The People's Republic of China, Hong Kong, Taiwan (unfortunately this country seems to have withdrawn), Indonesia, Thailand, Philippines, Malaysia, Singapore and Vietnam, CSK seems to be a good program for improving marine sciences in general and particularly for promoting cooperation in oceanographic research of the western part of the Pacific Ocean. For instance, Dr. Jotaro Masuzawa, now Director-General of the Japan Meteorological Agency, once stated in his acceptance speech of the OSJ Award that he obtained special worldwide insight and experience on oceanography by cooperating with oceanographers of the Southeast Asian countries.

The official report on WESTPAC may be obtained from UNESCO, IOC, Paris. I am writing a rather opinionated report in the spirit of Dr. Francis Richards. He wrote once in this Bulletin [*4*(3), 45 (1979)] about the existence of two schools of physical oceanography in Japan, the Todai (Tokyo University) school and the Kyodai (Kyoto University) school. This view is quite true but Japanese oceanographers are reluctant to admit it.

According to a UNESCO document, the first session of the Working Group for the WESTPAC Program was held in Tokyo on 21-24 February 1979 [this *Bulletin* *4*(2), 71-73 (1979)]. One of its decisions was to hold a workshop on CTOP in Japan during 1979-80, with Professor Toshiyaki Hirano, of the Ocean Research Institute of Tokyo University as the convener. Another document reveals that an international workshop on marine pollution in East Asian waters was convened at Malaysia University of Penan 7-13 April, 1976, sponsored by UNESCO, IOC and other UN subsidiary organizations. In this workshop the effects of different kinds of pollutants, including oil, pesticides, heavy metals, silt, thermal, radioactive wastes, and other industrial wastes on the environment were widely treated. The disciplines covered biology, chemistry, geology, and physical oceanography and the regions of study were those from the Bay of Bengal to the Japan Sea and the Seas of the Eastern Archipelago. This workshop recommended four major projects and twenty sub-projects. It is not clear how these proposed projects were carried out. A new workshop on CTOP thus seemed justified.

Preparation for the workshop was started in June 1979 by Hirano. The final agenda of the meeting was sent to invited participants in February, 1980, announcing the date and the meeting place at Asia Kaikan (Asia Center of Japan) in Tokyo. Another workshop on the marine geology and geophysics of the Northwest Pacific was held concurrently at the same place. The U.S. participants in the CTOP workshop were Drs. Don Pritchard and Jerry Schubel from State University of New Yo k at Stony Brook, and Professor Roy Hann and I from Texas A&M University.

The total number of participants was about 22, with an additional three to five observers in each session. The chairman and rapporteur were Schubel and Dr. M. Tomczak of Australia, respectively. The first day and morning of the second day were devoted to review papers on progress of research and problems in different countries, including Australia, P.R.C., Japan, Korea, Malaysia, Thailand and U.S.S R. International programs for monitoring oil spills and the training of personnel for this purpose were presented by Hann. The P.R.C. delegates (Mr. X. Quin, Ms. L. Tang and Mr. Q. Xu) revealed that industrial pollution has become serious in several coastal provinces, notably along the coast of Bohai Bay and in the estuary of the Yangtze. The Republic of Korea (Drs. S. Change and K-W. Lee) also suffers some pollution problems from industrial wastes, particularly in the Korean Strait and the Yellow Sea coast, and has started bimonthly survey programs by monitoring water quality and other hydrographic data on a number of transects in these areas. Malaysia (Mr. P. H. C. Tan), together with Singapore and Indonesia, face particularly difficult problems with possible disasters from oil spills in the Malacca Straits, where it is reported that tanker passages are more frequent than the AMTRAK schedule between New York and Washington, D C. So far, only strict navigation control has prevented tanker mishaps. The Gulf of Thailand (Dr. P. Menasvata and Ms. A. Siripong) suffers from agricultural pollution and silting. Monitoring with satellite imagery is planned Australia (Dr. Tomczak) has pollution problems from heavy metals, hydrocarbons, and pesticides, but monitoring programs are mainly for chemistry, geology and fisheries and rarely include physical oceanography. The Pacific Oceanology Institute of Vladivostok (Dr. V. Akulichev) is studying oil spill transport and the discharge of toxic metal in the ocean and its effects. In Japan, (Drs. H. Nakata and T. Suzuoki and Mr. M. Hishida) the Inland Sea and other bays and estuaries suffered from red tides, oil spills, and oxygen depletion. Their impact on fisheries is assessed by field observations and by mathematical and hydraulic modelling. Also, Japan has started baseline studies and monitoring of hydrocarbons, heavy metals in the water column, and sediments along about 30 coastal standard transects of 100 to 300 n. miles and one oceanic standard transect along 137°E from the Japanese coast to 1°S.

During the afternoon of the second day, review papers on selected topics were presented. I gave a summary report on an oil spill prediction model based on the horizontal turbulent diffusion with examples for a proposed St. Thomas (Virgin Islands) supertanker port. Dr. Pritchard discussed movement of water masses and pollutants in estuaries by sub-tidal frequency motions from observations of the Chesapeake Bay. Dr. T. Yanagi of Ehime University reviewed the studies on pollutant transport by tidal residue currents for different coastal topography of the Inland Sea.

The remaining days were devoted to discussing and drafting recommendations for research and training programs. In contrast to the 1976 Workshop, we made only seven recommendations on research projects, besides the training projects, which consist of standardization of pollutant sampling and analysis and establishment of data exchange systems. These research programs include

- obtaining data on currents and tides in the coastal waters,
- cooperative monitoring of pollutant transport in the Sea of Japan, the Yellow Sea, Bohai Bay and the East China Sea which are affected heavily by industrial and domestic wastes,
- long-term monitoring of sediments from river discharge,
- transport and accumulation of fine-grained sediments and of agricultural chemical residues,
- prediction and monitoring of spilled oil, and
- exchange processes at coral reefs.

The justification and long- and short-range objectives are stated for each proposed project. It is to be seen how these recommendations will be implemented in the futu in each national government and by international organizations.

OCEANOGRAPHICAL SOCIETY OF JAPAN (OSJ) MEETING

The OSJ is the largest society on oceanography in Japan, with a membership of more than 1500, including 125 foreign members, in March 1979 It publishes the bimonthly Journal of Oceanographic Society of Japan (JOSJ). This is one of the few publications in oceanography which are referred journals, it also prints most papers in English In Japan, many periodicals in oceanography are published by governmental organizations like the Japan Meteorological Agency, the Hydrographic Department and regional fisheries institutes, as memoirs from different universities or, as occasional publications from the Japan Academy or Ministry of Education. The OSJ was established in 1941, but is not the oldest oceanography society. The oldest is the Marine Meteorological Society, started at Kobe Marine Observatory in the early twenties The latter has published "Umi to Sora" (Sea and Sky), mostly in Japanese, since 1921 The other society is La Societe franco-japonaise d-oceanographie, started in 1962 by Dr Tadayoshi Sasaki, who specialized in marine optics, spent a year or two in France and is now president of Tokyo University of Fisheries (and also the president of La Societe)

This society publishes the quarterly journal La mer ("Umi" in Japanese) which contains a fairly large percentage of English papers, with almost the same number in Japanese, but very few French, papers. This society was started to improve Japanese and French cooperation in the marine sciences. Its membership is about 500.

The current president of the OSJ is Dr. Tosio Nanniti, formerly director of the Oceanographic Lab of the Meteorological Research Institute. Professor Koji Hidaka was the president for 19 years until 1967, and Professor Yasuo Miyake was president for several years. The annual meeting is usually held in Tokyo in April, with a fall meeting in October in another part of Japan. Dr. Richards attended the 1978 fall meeting held in Sapporo, Hokkaido. Both meetings offer good opportunities for academic and governmental oceanographers, and Tokyo and local oceanographers to meet together. Unlike the American Geophysical Union or the American Society of Limnology and Oceanography, membership and participation in annual meetings of the OSJ covers all five disciplines, physical, chemical, biological, geological and geophysical oceanography, though geological and geophysical fields are underrepresented, and physical oceanography overrepresented, compared to the current census of Japanese oceanographers in each discipline. This tendency was particularly strong in the 1980 annual meeting, in which 106, 52, 35 and 4 papers were presented from April 6 through 8 for physical, biological, chemical and geological-geophysical oceanography, respectively. Marine geology and geophysics including tectnophysics papers are usually presented at Japanese Geological Society and Seismological Society meetings.

Coverage in physical oceanography was quite broad. The numbers of papers in different subjects are as follows:

- descriptive in the deep sea 18,
- descriptive on nearshore and estuaries 29,
- theoretical and other modelling of large scale circulation 7,
- modelling of small scale circulation 9,
- surface waves 12,
- remote sensing 15,
- marine optics 5,
- beach and bottom processes 4,
- seiches and tides 4,
- and instrument 3 although some papers cover two or three of these topics.

Descriptive and theoretical papers were more on nearshore and estuaries than on blue water oceanography in contrast to the AGU Oceanography Section meeting. This is mainly because participants in the meeting come more from academic institutions than from governmental agencies, which have overwhelmingly large numbers of ocean-going research and survey vessels (about fourteen against four, excluding training ships, according to this *Bulletin 3*(3), 34-36 (1978), and because the governmental support of academic oceanographic research has been heavily focused towards environmental problems in bays and estuaries in recent years. Remote sensing, mainly based on satellite data, is now a popular topic in Japan, particularly for monitoring pollution and fishery resources as discussed later.

The meeting was held concurrently in three classrooms at the Yoyogi (Tokyo) campus of Tokai University with three sessions each morning and afternoon. Each session consisted of three to five papers dealing with similar topics with a 15-minute talk followed by 2-3 minute discussion for each paper. Each session seemed to be well attended by 60-100 people. Because of the rather heavy schedule, discussions were sometimes perfunctory but seemed to be always courteous, more so now than about 25 years ago when I last attended. The preprints of the meeting is much better than in meetings of the U.S., because each paper is allowed two pages of handwritten manuscript with figure reduced to about 15 cm X 22 cm, 68% of the original sheet by offset printing. Since Japanese writing is much more concise than western languages, many papers in the preprint seem to represent almost their full contents.

Most sessions were devoted to separate fields, but in some sessions, particularly for remote sensing, physical and biological oceanography papers were intermixed. Six announced, and two additional special, symposia were devoted to interdisciplinary topics on:

- fisheries oceanography,
- dumping of low-level radioactive wastes,
- nearshore bottom processes,
- roles of plankton and bacteria on material transfer in the ocean,
- methodology of marine environmental assessment,

– application of remote sensing, and
– planning of the Japanese activities for the CRP (Climate change and variation Research Program) for the WCP (World Climate Program).

I attended the last two symposia. The symposium on remote sensing was sponsored by the newly established Society of Airborne and Satellite Fisheries Oceanography (president, Professor Mitsuo Iwashita of Tokai University), which publishes the quarterly journal "Sora to Umi" (Sky and Sea) mainly in Japanese and partly in English. I asked the editor, Professor Yashuro Sugimori of Tokai University, whether there is a legal problem with the journal title which is very similar to the journal of the Marine Meterological Society. It seems to be no such problem in Japan because there is an understanding (and dual membership) between the two groups. At the symposium, nine papers were presented dealing with various subjects on the application of satellite imagery to hydrography and fisheries, and also a prospectus of the Japanese Marine Observation Satellites (MOS) up to 1993 (four MOS are expected to begin operation by 1983) by a representative of NASDA (the National Artificial Satellite Development Agency). I was invited to speak on the proposed program of using satellite imagery (Nimbus 7 and others) for oceanography near the three straits of the Japan Sea starting next year.

The last symposium on the CRP was convened by Professor Yoshiaki Toba of Tohoku University and attended by 30 people, mainly from academic institutions. The Japanese oceanographers and climatologists are interested in analysis of the long-term change of the sea surface temperature, monitoring of the temperature in the North Pacific, particularly the sub-tropical regions and modelling for sea surface temperature prediction by combining atmospheric and oceanic circulation models. It was decided that Toba will send questionnaires among a wider group of prospective participants later in order to form more concrete programs in this respect. I volunteered to stress the importance of the Japan Sea for long-term variation studies, both because of its effects on the Northwestern Pacific by exchange through the straits and because it is manageable by one or two countries due to its small size.

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LABORATORY OF BIOGEOCHEMISTRY AND SOCIOGEOCHEMISTRY OF THE MITSUBISHI-KASEI INSTITUTE OF LIFE SCIENCES

Francis A. Richards

What is sociogeochemistry and what do sociogeochemists do? The concept of biogeochemistry is well established, but *sociogeochemistry*? When I asked this question of the director of the laboratory, Dr. Eitaro Wada, he was rather amused and slightly confused. "I think it means what we want it to mean," was his approximate answer He then went on to explain that the objectives of the laboratory were purposely left vague by the parent institute to give a rather free rein to the young scientific staff that had been assembled. It is significant that Wada had taken his doctorate in geochemistry under the eminent Professor Yasuo Miyake, at the former Tokyo University of Education, which has now been absorbed in the new Tsukuba University. After graduation, Wada spent a post-doctoral of 14 months at the University of Texas, where he worked with Professor P. L. Parker, who is well-known for his studies of biogeochemical processes through the use of stable isotopes, especially carbon-13 (^{13}C). Wada also served at the Ocean Research Institute of Tokyo University in the Marine Beochemistry Division with Professor Akihiko Hattori, working on various aspects of the biological nitrogen cycle in the ocean. Upon his appointment to the Institute of Life Sciences, he was sent for an additional year's study of agrictultural chemistry at Tokyo University. His background and special training have been dominant in determining the course of research in his laboratory.

The Laboratory of Biogeochemistry and Sociogeochemistry is one of 11 life sciences laboratories, five special research groups, and two administrative sections that make up the institute, which began operation on 1 June, 1977, having been formed by the late president of the Mitsubishi Chemical Company, Mr H Shinojima The first and present director of the institute is Dr. Fujio Egami, a retired professor from Tokyo University The general nature of the research fields is suggested by the names of the laboratories biophysics, biological activities of biopolymers, biochemical reactions and biocatalysts, microbiological chemistry, cell biology, developmental biology, neurophysiology, physiological psychology, neurochemistry, pharmacology, and biogeochemistry and sociogeochemistry There are groups for biochemical preparations, organochemical preparations, the Nakashibetsu serum preparation center, the social life sciences, and the director's group. The director is interested in the origin of life and the activities of this group reflect that interest

The institute is at 11 Minamiooya, Machida-shi, Tokyo 194, Tel. 0427-26-1211, and is easily reached by express train from Shinjuku. It has two main research buildings, animal and micro-organism culture buildings, a seminar and dining room building, and a building for administration and utilities. Typical of many companies and government laboratories in Japan, there are apartments and dormitories for employees. The first building was completed in 1972, the second building phase in 1977. The grounds are nicely landscaped and tended, altogether both the interior and exterior of the institute are pleasant and attractive. I was pleased that the Japanese and American flags were flying to mark my visit

The staff of the Laboratory of Biogeochemistry and Sociogeochemistry consists of Wada, Drs Masao Minagawa, Hiroshi Mizutani, and Takashi Tsuji, a predoctoral fellow from the University of Tokyo, Mr Koichi Nakamura, and two research assistants, Ms. Mikie Ogii and Ms Reiko Shibata The main research themes of the laboratory are

- nitrogen isotope ratios in biogeochemical systems
- studies of carbon isotopes
- measurement of standing stocks of red tide phytoplankton by an image processing system
- biogeochemical studies of Lake Ashino-ko
- basic studies on nutrient dynamics in paddy water

Generally each staff member has a lead role in one of the theme projects, but annually one project is selected as a group effort and the various specialties of the staff members are called upon to take an integrated approach to bio geochemical system In 1979 the group project was the study of Lake Ashino-ko, a lake in Hakone National Park about 12 km long and 1 to 1-½ km wide From June to November, water, plankton, and sediment core samples were collected monthly for chemical and isotopic studies, and concentrations of suspended matter and the vertical distribution of temperature were observed during the period.

Temperatures followed a typical seasonal pattern with a well-developed thermocline between 10 and 18 meters persisting through the period; maximum temperatures, over 23°C, were observed at the surface on 5 September. Suspended matter was generally low, and a small maximum, over 6 mg per liter, occurred at 6 meters during the September sampling Although the lake was described as oligotrophic in 1937, there has been some eutrophication in recent years and the lake ecology is beginning to reflect the impingement of the activities of man.

Perhaps even more interesting than the impingement of man on the lake water is the history of the volcanic activity of Mt Fuji as recorded in pumice layers in the lake sediments. A 20-cm gravity core from the northern part of the lake contained three pumice layers, which could be dated from the relatively low sedimentation rate of 0.2 millimeters per year, which was in turn estimated from the vertical distribution of the isotope lead-210 in the core. The depths (ages) of the pumice layers thus estimated agree well with the historical records of the volcanic activity of the mountain–999 to 1083, 1511 to 1560, and 1700 to 1707 AD.

The organic nitrogen content of the core, as determined by the Kjeldahl method, decreases with depth. Combining the rate of decrease with the sediment accumulation rate permits an estimate of the average rate of decomposition of organic matter of 47 micrograms of nitrogen per gram of dry sediment per year for the past 200 years.

The sedimentation rate in the southern part of Ashino-ko is considerably higher than in the northern part–0.8 mm per year vs. 0.2 mm per year, and the nitrogen isotopic ratios of the dissolved nitrogen compounds in deep sediments also differ The ratios in the deep sediments from the north are nearly the same as the reference standard-atmospheric nitrogen, but the $\delta^{15}N$* value is about +3‰, meaning that the nitrogen is relatively richer in the heavy isotope, nitrogen-15, than in nitrogen-14. Isotopes of differing atomic weight are fractionated by various physical and biological processes, so the ratios of the isotopes in various materials reflects the history and processes the material has gone through. For example, the $\delta^{15}N$ is about +7 to 9 in plankton, +11 in fish In the sediments, the water-soluble (exchangeable) nitrogen is 2 to 3‰ heavier than the fixed nitrogen. Thus, the nitrogen isotope studies are useful in helping to understand the past and present ecology of the system.

The theme of the laboratory group project for 1980 is the geochemical study of the Ohtsuchi water system. The specialties of all members of the laboratory will be brought to bear on understanding the system from studies beginning with the headwaters of the Ohtsuchi River, through its mixing and transport through the bay, and finally its influence on the coastal zone Subjects include the transport of nutrient chemicals and other elements from their introduction to the system from the air via precipitation and by leaching from the soil to their entry into the ocean. Variables to be observed are ratios of the stable isotopes of carbon and nitrogen, radioisotopes, organic geochemicals, nutrient concentrations, and the concentration and composition of standing stocks of the biota, especially the phytoplankton and zooplankton.

Several subprojects of the laboratory are included in the general theme of nitrogen isotope ratios in biogeochemical systems Nitrogen isotope ratios are the special interest of Dr Wada, who uses them to study paddy soils, in investigations of marine plankton, their changes associated with denitrification in soil water systems, and nitrogen isotope fractionation along the food chain.

Studies of the ^{15}N abundance in paddy soils from five agricultural experiment stations in Japan showed that the ^{15}N content of the organic matter decreased as the organic matter increased, probably because of the large isotope fractionation occurring during denitrification, leaching, and volatilization of ammonia. Forest systems have been investigated in three regions in Japan Values of $\delta^{15}N$ tend to increase with depth in the soil while the total nitrogen (Kjeldahl) decreases At the surface, values of $\delta^{15}N$ are low, about 2‰, where the source of nitrogen compounds is precipitation and nitrogen fixation The isotope ratios are altered as free ammonia ions exchange with potassium and calcium clays

$$^{15}NH_4^+ + {}^{14}NH_4X \rightleftharpoons {}^{14}NH_4^+ + {}^{15}NH_4^+X$$

*$\delta^{15}N$ is defined as follows

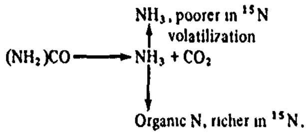
$$\delta^{15}N = \frac{^{15}N\,(\text{sample}) - {}^{15}N\,(\text{standard})}{^{15}N\,(\text{standard})}$$

It is expressed as parts per thousand, ‰

where X is a clay. The fractionation factors differ for exchanges with potassium and calcium saturated clays. The resulting equilibrium ratios are complex functions of the clay composition, the permeation of ground water, nitrogen fixation, denitrification, volatilization of ammonia, and other processes

Values of $\delta^{15}N$ were low in cells of *Trichodesmium* spp. and associated zooplankton from the East China Sea *Trichodesmium* is generally considered to be responsible for nitrogen fixation under certain circumstances in the ocean The low $\delta^{15}N$ values suggest an atmospheric origin and therefore nitrogen fixation. The low $\delta^{15}N$ values in *Trichodesmium* cells were associated with low concentrations of nitrate-nitrogen in the euphotic zone, also suggesting that fixation of atmospheric nitrogen is the principal source of combined nitrogen In boreal areas, where nitrate ions are abundant in the photic zone, $\delta^{15}N$ values are high, but in light limiting cases, epibenthic algae grown in the presence of high nitrate concentrations show high fractionation factors and correspondingly low values of $\delta^{15}N$.

Exotic communities in which Wada has been studying nitrogen isotope fractionation are three Antarctic ecosystems—Victoria Land, the dry valleys, and a Ross Island penguin rookery. The nitrates in Antarctic soils have large negative values of δ^{15} N (relative to atmospheric nitrogen) suggesting that the nitrates in Antarctic soils originate from atmospheric phenomena, precipitation, and auroral activity. Extreme values, -23.6‰, -21.2‰, and -20 6‰, were found in nitrates in soil materials from Lake Vanda (77°30'S, 161°40'E). In contrast, high values were found in the organic fraction of soil nitrogen from the Cape Bird, Ross Island, penguin rookery (+28 6‰) and in epibenthic algae from the same region (+30.7‰). The fractionation of the isotopes probably follows a scheme such as



The high ratios at the rookeries result from the birds' "heavy nitrogen" diet of fish and additional fractionation as indicated above. These processes may also account for extremely low values (-47 8, -49 0‰) observed in the epibenthic algae in an unnamed saline pond on the edge of the Wright upper glacier (77°32'S, 160°45'E).

Until now Dr. Wada has had to content himself with samples from Antarctica collected by other workers, but he will join the Japanese Antarctica Research Expedition in the austral summer of 1980 81 to do his own sampling and observations.

To study nitrogen isotope fractionation along the food chain, laboratory animals were fed diets of constant isotopic composition and then analyzed. The whole bodies of the brine shrimp, *Artemia* sp , and of tropical fish, *Lebistes* sp , were enriched in ^{15}N by about 4‰ relative to the diet Natural samples were also collected from both aquatic and terrestrial ecosystems to determine the isotopic composition of animals and dietary organisms along the food chain As in the laboratory studies, the ^{15}N in the whole body of an animal is about 4‰ higher than that of its diet, regardless of the isotopic composition of the diet The enrichment may result during biochemical nitrogen metabolism This view is supported by the fact that ammonia nitrogen-15 excreted by the fishes was about -15‰ lower than that of the diet

Koichi Nakamura is a pre-doctoral associate at the laboratory and a graduate student in soil science in the Department of Agricultural Chemistry of Tokyo University He is concerned with the dynamics of stable carbon isotopes, especially in paddy fields. Experimental paddy fields at the Central Agricultural Experiment Station, Konosu, Saitama Prefecture, have recorded fertilizer histories since 1928 Four plots were studied and the $\delta^{13}C$ PDB (referred to the Pee Dee Belemnite Standard) differed significantly with the fertilizer history of the plot The values of $\delta^{13}C$ in the non-fertilized plot were greater than those in the plot that receives 10 kg N as ammonium sulfate per 100 acres per year The $\delta^{13}C$ values in the latter were much greater than in a plot that received the same amount of fertilizer nitrogen as a mixture of soybean lees and farmyard manure, which was in turn richer in ^{13}C than a plant that received its nitrogen as Chinese vetch green manure Seasonal variations of ^{13}C values in the soil during submerged periods (June through September) were followed in the Oto 1-cm (oxidized) soil layer and in the 5 to 10 cm (reduced) deep layer The ^{13}C values in the upper layer did not change much, but they increased during the period in the deeper stratum Thus, the CO_2 in the reduced layer is richer than in the oxidized soil Incubation of the reduced soil under anoxic conditions at 27°C for a week resulted in a decrease in the amount of CO_2 and an increase in ^{13}C values

During incubation under oxidizing conditions there was a higher production of CO_2 with lower values of $\delta^{13}C$ than in the organic carbon Under anoxic conditions methane was also produced, but the $\delta^{13}C$ values in the CO_2 were not closely related to the CH_4 product, so alternate metabolic pathways are being investigated Respiration, fermentation, and dark carbon fixation by soil microorganisms evidently are important in regulating the carbon isotopic ratios in various types of organic matter in soils In any case, information on stable carbon isotope distributions is proving useful in the study of short term carbon cycling processes (epidiagenesis).

Carbon isotopes are also being used to study isotope fractionation during photosynthesis (in laboratory cultures) of thermophilic algae by Dr Hiroshi Mizutani During the Pleistocene, plants using the C_4 photosynthetic pathway evolved from C_3 plants They were more effective in utilizing CO_2 and could grow at much lower partial pressures of CO_2 than could their ancestors. C_3 plants have lower $\delta^{13}C$ values (-16 to -26‰) relative to atmospheric air than do C_4 plants (+2 to -11‰) Although generally considered to be C_3 plants, algae have values from -4 to -15‰, suggesting they may utilize the C_4 pathway during an induction period Thermophilic blue green and green algae were collected from various hot springs and cultured in the laboratory, using ambient atmospheric CO_2 as a carbon source The $\delta^{13}C$ value depended on growth conditions such as light intensity and temperature, in some cases the value was greater than -4, possibly because of the presence of a C_4 type pathway.

Changes in carbon isotope ratios have also been used to investigate the growth physiology of algae in extreme environments. A highly thermophilic alga, *Synechococcus* sp., and an acidophilic specos, *Cyanidium caldarium*, were grown under different conditions. Preliminary results suggest that C *Caldarium* uses gaseous CO_2 instead of dissolved bicarbonate as a carbon source and that the extent of photosynthetic isotope fractionation depends strongly on the partial pressure of the feed gas. Continued studies are planned in an attempt to understand the paleoenvironments in which these and other algae prevailed

Drs. T Tsuji, T Nishikawa and M. Ogu have developed a new method for measuring the standing stock of red tide phytoplankton by an image processing system Samples of natural populations of phytoplankton were photographed simultaneously under optical and fluorescent microscopes. The microphotographs were then analyzed by an image analyzer system including a host Facom 230-55 computer, a Fujitsu Co. Ltd., U-300 front Minicomputer, and a Kowa C. Ltd , OS701 optical pattern reader recorder The images were first scanned, converted to digital form, and accumulated by the OS-701 and U-300 A prototype, the most typical organism among a population, was then processed The Facom 230-55 selected cells that resembled the prototype using 14 parameters such as density, area, maximum diameter, and eccentricity The 14 parameters were measured for each selected phytoplankter, and a histogram of phytoplankton numbers against each parameter was displayed on the line printer.

The new method has been applied to the measurement of standing stocks of red tide phytoplankton in Tokyo and Sagami bays At the time of sampling, a red tide was evident in Tokyo Bay but not in Sagami Bay The size distributions at some stations in Tokyo Bay are shown in the figure The distributions reflect that nutrient concentrations in Tokyo Bay are 10 times those in Sagami Bay and suggest that small phytoplankters (from 3 to 21 nm) can grow even in low nutrient concentrations, but that larger organisms, such as *Prorocentrum triestinam* (a dinoflagellate, 20 to 33 nm), can grow only in high nutrient concentrations

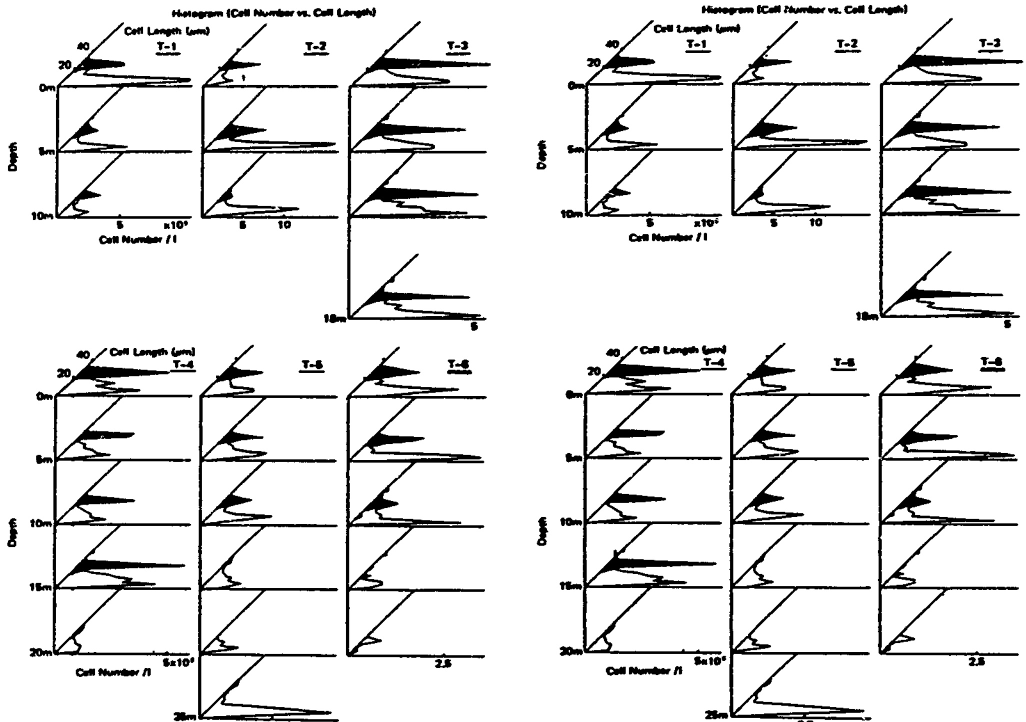
Other than the lead-210 dating work already referred to, other work with radioactive nuclides is just beginning at the laboratory Observations designed to measure time scales in ecosystems using such radionuclides as ^{234}Th (half life 24 days), ^{210}Po (half-life 138 days), and ^{210}Pb (half life 22 years) are planned to help assess environmental fluctuations and to establish what Dr Wada calls "ecochronology " At the time of my visit the laboratory was equipped only to measure alpha emitters using an Altec alpha spectrometer They plan to expand their capabilities to the measurement of ^{240}Pu, ^{232,228}Th, and ^{226}Ra

The laboratories are functional, well equipped for the work they are doing, and well maintained Special rooms or laboratories are maintained an algal culture room and incubation systems for culturing thermophilic algae and algae under other extreme conditions, a cold room kept at 4°C + 0 2 or 0 3°C, a room for sterile transfers, and a wet chemistry laboratory. Specialized equipment includes

- fluorescence spectrophotometer for measuring chlorophyll
- fluorescence microscope for the image processing work
- low temperature centrifuge

- Shimadzu UV-210A double beam spectrophotometer
- laboratory made automatic analyzer. Its use in estimating nitrite has just begun.
- Ortec Model 6240B multichannel alpha spectrometer (made by EG and G, U.S.A.).
- Varian carbon furnace system atomic absorption spectrophotometer with tubes for Pb, Co, Zn, K, Cr, Cd, Mg, Ti, Ta, Al, and V.
- Hitachi RMU-GR mass spectrometer, used for nitrogen and carbon isotope determinations.
- nitrogen gas purification system including carbon and copper oxide furnaces.

The above account is not complete, but it gives an impression of the comprehensive scope of the activities of the laboratory. Also, when we realize the social importance of such things as the ecology and geochemistry of rice paddies and forests, of the eutrophication of many of Japan's waters, and of estuarine and aquatic system in general, the term sociogeochemistry becomes not only understandable but entirely accurate.



Size distribution of phytoplankton in Tokyo Bay and Sagami Bay.
Shaded area shows *Prorocentrum triestinum*.

INTERNATIONAL MEETINGS IN THE FAR EAST

1981-1983

compiled by Seikoh Sakiyama

It is intended to update and augment this list in future issues of the Scientific Bulletin. The assistance of Dr. T. D. Grace, Australian Embassy, Tokyo, and Dr. M. J. McNamara, New Zealand Embassy, Tokyo, in supplying a listing of meetings in their countries is deeply appreciated. Similarly, the assistance of Dr. Robert Stella, American Embassy, New Delhi (formerly in Seoul), in supplying a listing of meetings in Korea is deeply appreciated. Readers are asked to notify us of upcoming international meetings in the Far East which have not yet been included in this list.

1981

Date	Title	Site	For Information, Contact
January 25-31	International Symposium on Erosion and Sediment Transport in Pacific Rim Steeplands	Canterbury, New Zealand	Royal Society of New Zealand Box 12249, Wellington
January 31-February 4	Conference on Large Earthquakes	Napier, New Zealand	Royal Society of New Zealand Box 12249, Wellington
February 8-11	Second Australian Colloid Conference	Terrigal, Australia	Assoc. Professor D. H. Napper, School of Chemistry, University of Sydney, Sydney, NSW, 2006
February 11-18	International Conference on Soils with Variable Charge	Massey, New Zealand	Royal Society of New Zealand Box 12249, Wellington
February (tentative)	Fifth International Conference on Ion Beam Analysis	Sydney, Australia	Professor J. C. Kelly, Department of Physics, University of NSW, PO Box 1, Kensington, NSW, 2033
March 5-10	1st International Seminar on Semiconductor Processing	Gumi, Korea	Mr. K B. Whang, Director Korean Institute of Electronics Technology
March 13-14	The 2nd International Symposium on Hemophilia Treatment	Tokyo, Japan	Prof. T. Abe Teikyo University School of Medicine 2-11-1 Kaga, Itabashi-ku, Tokyo 173
March 16-21	IUPAC-IUTAM Symposium on Interactions in Colloidal Suspensions	Canberra, Australia	Professor B W Ninham, Research School of Physical Sciences, Australian National University, Canberra
March 20-21	The Second International Symposium on Bone, Structure, Function & Disease	Adelaide, Australia	Dr M. J. Hooper, Royal Adelaide Hospital North Terrace, Adelaide, SA, 5000

1981–Continued

Date	Title	Site	For Information, Contact
March (tentative)	Ecotoxicological Problems in the Indo-Pacific Region	Taipei, Taiwan	Dr. Jong-Chin Su Institute of Zoology Academia Sinica Taipei 115
April 13-17	International Telecommunications Conference	(undecided) New Zealand	NZ Post Office Wellington
April 26-May 1	1st Asian and Pacific Chemistry Congress	Singapore, Republic of Singapore	The Congress Secretary 1st Aspac Congress Singapore Professional Center 129B Block 23 Ontram Park Singapore 0316 Republic of Singapore
May 4-8	Annual Scientific Meeting of the Australian Society for Microbiology	Canberra, Australia	V. A. Stanisich, Australian Society for Microbiology, 191 Royal Parade, Parkville, Vic, 3052
May 11-14	12th Australian Polymer Symposium	Blackheath, Australia	D. F. Sangster, AAECRE, Private Mail Bag, Sutherland, NSW, 2232
May 11-15	4th International Symposium on Trace Element Metabolism in Man & Animals (TEMA-4)	Perth, Australia	Dr. E. J. Underwood, Chairman, Organising Committee, TEMA-4, c/o Department of Animal Science, University of WA, Nedlands, WA, 6009
May 11-15	Australian Biochemical Society Annual Meeting	Adelaide, Australia	Dr. H. C. Robinson, Department of Biochemistry, Monash University, Clayton, Vic, 3168
May 11-15	4th International Conference on Trace Metabolism in Man & Animals (TEMA)	Perth, Australia	Australian Academy of Science, PO Box 783, Canberra City, ACT, 2601
May 18-22	Fourth International Coral Reef Symposium	Manila, Philippines	Marine Sciences Center, IV CRS University of the Philippines P O. Box 1 Diliman, Quezon City 3004
May 23-30	The 12th Conference of the International Association of Ports and Harbors	Nagoya, Japan	Nagoya Port Authority 1-8-21, Irifune, Minato-ku, Nagoya 455

1981–Continued

Date	Title	Site	For Information, Contact
May 25-29	International Tsunami Symposium 1981	Sendai, Japan	Professor E. Kajiura Earthquake Research Institute University of Tokyo 1-1, Yayoi 1-chome, Bunkyo-ku Tokyo 113
May (tentative)	34th Annual Metals Congress	Sydney, Australia	undecided
May (tentative)	Electric Energy Manufacturing Conference	(undecided) Australia	The Institution of Engineers, Australia, 11 National Circuit, Barton, ACT, 2600
June 6-7	The 4th International Symposium on Quality Control - Osaka	Kobe, Japan	Secretariat, ISQC-Osaka Kobe Minato P.O. Box 569, Hyogo 651-01
June (tentative)	ROK-ROC Seminar on Oceanography	Seoul, Korea	Korea Ocean Research and Development Institute P.O. Box 17, Yang-Jae, Seoul
June 28-July 2	Fifth International Conference Geochronology, Cosmochronology and Isotope Geology	Nikko, Japan	Dr. K. Shibata Geological Survey of Japan 1-1-3, Yatabe-cho Higashi Tsukuba-gun, Ibaraki 305
June 29-July 3	The VIIth International Symposium on Gnotobiology	Tokyo, Japan	Prof. S. Sasaki Chairman, Organizing Committee VII International Symposium on Gnotobiology, Dept. of Microbiology, School of Medicine, Tokai University, Bohseidai, Isehara-shi, Kanagawa 259-11
July 19-24	8th International Congress of Pharmacology–IUPHAR–	Tokyo, Japan	The Japanese Pharmacological Society Gatsukai Center Bldg. 4F., 2-4-16, Yayoi, Bunkyo-ku, Tokyo 113
July 27-August 1	The 4th International Congress of Biorheology	Tokyo, Japan	Japanese Society of Biorheology Physics Laboratory, Keio University 4-1-1, Hiyoshi, Kohoku-ku, Yokohama 223
August 10-14	International Congress of Pharmocology	Sydney, Australia	Australian Academy of Science, P.O. Box 783, Canberra City, A C.T 2601
August 17-21	21st Conference on Physical Sciences & Engineering in Medicine and Biology	Melbourne, Australia	Mr. K. H. Clarke, Department of Physical Sciences Cancer Institute, 481 Little Lonsdale St., Melbourne, Vic, 3000

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August 21-28	XIII International Botanical Congress	Sydney, N.S.W. Australia	Executive Secretary, Dr. W. J. Cram, School of Biological Sciences, University of Sydney N.S.W., 2006
August 23-28	Sixth Australian Symposium on Analytical Chemistry (6AC)	Canberra, Australia	Hon. Secretary, Miss B. J. Stevenson, PO Box 1397, Canberra City, ACT, 2601
August 24-26	Vth International Conference on Electrical Bio-impedance	Tokyo, Japan	Prof. K. Nakayama, Dept. of Electrical & Electronic Engineering, Sophia University 7 Kioicho, Chiyoda-ku, Tokyo 102
August 24-28	4th International Conference on Rapidly Quenched Metals	Sendai, Japan	The Japan Institute of Metals Aramaki Aoba Sendai, Miyagi 980
August 24-28	International Federation of Automatic Control (IFAC) 8th Triennial World Congress	Kyoto, Japan	Prof. Y. Sawaragi Dept. of Applied Mathematics and Physics, Faculty of Engineering Kyoto University Yoshida-Honmachi, Sakyo-ku Kyoto 606
August 26-27	Symposium on Stress Analysis for Mechanical Design 1981	Sydney, Australia	The Conference Manager, The Institution of Engineers, Australia, 11 National Circuit, Barton, ACT, 2600
August (tentative)	17th Annual Congress of the Australian and New Zealand College of Psychiatrists	Victoria, Australia	(undecided)
September 1-5	9th ICAS-XXII CSI (9th International Conference on Atomic Spectroscopy and XXII Colloquium Spectroscopium Internationale)	Tokyo, Japan	The Japan Society for Analytical Chemistry, 9th ICAS-XXII CSI Gotanda-Sanhaitsu 26-2, 1-chome, Nishi-gotanda Shinagawa-ku, Tokyo 141
September 12-18	The 10th International Congress of Electroencephalography and Clinical Neurophysiology	Kyoto, (undecided) Japan	International Conference Organizers, Inc., Crescent Plaza 103 2-4-6, Minami-Aoyama Minato-ku, Tokyo 107
September 17-21	The 14th World Congress of International League against Epilepsy and the 13th Symposium of the International Bureau of Epilepsy	Kyoto, Japan	International Conference Organizers, Inc Crescent Plaza 103, 2-4-6, Minami-Aoyama, Minato-ku, Tokyo 107

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September 20-23	1981 International Symposium on Gallium Arsenide and Related Compounds	Kanagawa, Japan	Prof. H. Yanai, Dept. of Electronic Engineering, University of Tokyo 7-3-1, Hongo, Bunkyo-ku, Tokyo 113
September 20-25	12th World Congress of Neurology	Kyoto, Japan	Simul International, Inc. No. 9, Kowa Bldg., 1-8-10, Akasaka, Minato-ku, Tokyo 107
September 23-25	Australasian Society of Nephrology joint meeting with Cardiac Society	Brisbane, Australia	Dr. B. M. Saker, Renal Unit, Royal Perth Hospital Perth, WA, 6000
September (tentative)	International Rock Mechanics Symposium on Weak Rock – Soft, Fractured and Weathered Rock	Tokyo, Japan	Japan Society of Civil Engineers 1-chome, Yotsuya Shinjuku-ku, Tokyo 160
October 4-7	4th Congress of International Society for Laser Surgery	Tokyo, Japan	Narong Nimsakul, M.D., Secretary General, 4th Congress of International Society for Laser Surgery, Department of Plastic Surgery, School of Medicine, Tokai University Boseidai, Isehara-shi, Kanagawa Pref. 259-11
October 7-9	Symposium on Industrial Robots and Robot Exhibit	Tokyo, Japan	Mr. Y. Komori Japan Industrial Robot Association Kikai Shinko Bldg. 3-5-8, Shiba-Koen Minato-ku, Tokyo 105
October 11-23	International Union Conservation of Nature and Natural Resources	Christchurch, New Zealand	Lincoln College, Christchurch
October 18-25	15th Annual Conference on Law of the Sea	Seoul, Korea	Korea Ocean Research and Development Institute P.O. Box 17, Yang-Jae, Seoul
Late October-Early November	FAI the 74th General Conference, 1981 (International Aeronautical Federation)	Tokyo, Japan	Japan Aeronautic Association 1-18-2, Shinbashi, Minato-ku, Tokyo 107
October/ November (tentative)	Seminar on Estuaries–their Physics, Chemistry, Biology, Geology and Engineering Aspects	Goa, India	Dr. R. Sen Gupta Convener, Seminar on Estuaries National Institute of Oceanography Dona Poula, Goa-403004
December (tentative)	Ninth International Symposium on Comparative Endocrinology	Hong Kong	Prof. B. Lofts Department of Zoology, The University of Hong Kong

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February (tentative)	7th Australian Electron Microscopy Conference	Canberra, Australia	Australian Academy of Science, PO Box 783, Canberra City, ACT, 2600
April/May (tentative)	Second International Workshop on the Malacofauna of Hong Kong and south China	Hong Kong	Dr. B. S. Morton Department of Zoology, The University of Hong Kong
May 10-14	Annual Scientific Meeting of the Australian Society for Microbiology	Hobart, Australia	Dr. J. Bould, Baas Becking Laboratories, PO Box 378, Canberra City, ACT, 2601
May 10-15	General Meeting of the International Association of Geodesy	Tokyo, Japan	Assistant Prof. I. Nakagawa, Geophysical Institute, Faculty of Science, Kyoto University Oiwake-cho, Kita-Shirakawa, Sakyo-ku, Kyoto 606
May 23-28	16th International Congress of Dermatology (CID)	Tokyo, Japan	Japan Convention Services, Inc. Nippon Press Center 8F 2-2-1, Uchisaiwai-cho Chiyoda-ku, Tokyo 100
May (tentative)	35th Annual Metals Congress	Sydney, Australia	Australasian Institute of Metals, PO Box 263, Bondi Beach, NSW, 2026
June 7-11	9th International Congress on Electrocardiology (23rd International Symposium on Vectorcardiography)	Tokyo, Japan	Tokyo University School of Medicine 7-3-1 Hongo, Bunkyo-ku, Tokyo 113
June 7-11	Fourth International Symposium on the Genetics of Industrial Microorganisms	Kyoto, Japan	GIM Japan National Committee Microbiology Research Foundation 2-4-16 Yayoi, Bunkyo-ku, Tokyo 113
June (tentative)	Twelfth International Conference of Biochemistry	Sydney, Australia	Prof. W. H. Elliot Biochemistry Department, University of Adelaide, Adelaide. S.A. 5000
July 5-10	VI International Symposium on Solute–Solute–Solvent Interactions	Osaka, Japan	Prof. H Ohtaki, Tokyo Institute of Technology at Nagatsuta, Department of Electronic Chemistry Nagatsuta, Midori-ku, Yokohama 227
Mid-July (tentative)	The 5th International Congress of Plant Tissue	Yamanashi, Japan	Assistant Prof. A Komamine Dept of Botany, Faculty of Science University of Tokyo 7-3-1, Hongo, Bunkyo-ku Tokyo 113

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August 9-September 3	The 5th International Congress of Pesticide Chemistry, IUPAC	Kyoto, Japan	Rikagaku Kenkyusho 2-1, Hirosawa, Wako Saitama 351
August 15-21	International Biochemical Congress	Perth, Australia	Australian Academy of Science and International Union of Biochemistry P.O. Box 783, Canberra ACT 2601
August 22-27	Fourth International Conference on Organic Synthesis (IUPAC)	Tokyo, Japan	Prof. T. Mukaiyama, Department of Chemistry, Faculty of Science, University of Tokyo 7-3-1, Hongo, Bunkyo-ku, Tokyo 113
August (tentative)	The Royal Australian Chemical Institute 7th National Convention	Canberra, Australia	Executive Secretary, RACI HQ 191 Royal Parade, Parkville Vic. 3052
August (tentative)	13th Australian Spectroscopy Conference	(undecided) Australia	Australian Academy of Science PO Box 783, Canberra City, ACT, 2601
August (tentative)	1982 International Conference on Solid State Devices	Tokyo, Japan	The Japan Society of Applied Physics Kikai-Shinko-Kaikan 5-8, 3-chome, Shibakoen Minato-ku, Tokyo 105
August (tentative)	International Biochemistry Congress	Perth, W.A. Australia	Australian Academy of Science P.O. Box 783, Canberra City, A C.T. 2601
August 23-27	The 8th Congress of International Ergonomics Association	Tokyo, Japan	Masamitsu Oshima, Director The Medical Information System Development Center Landick Akasaka Bldg. 2-3-4, Akasaka, Minato-ku Tokyo, 107
September 5-10	International Conference on Magnetism–1982 (ICM–1982)	Kyoto, Japan	Prof. J Kanamori, Faculty of Science, Osaka University Toyonaka, Osaka Pref. 560
September 6-10	International Conference on Nuclear Physics in the Cyclotron Energy Region	Osaka, Japan	Prof M Kondo, Research Center for Nuclear Physics, Osaka University Yamada-kami, Suita-shi, Osaka 565
September (tentative)	6th International Symposium on Contamination Control	Tokyo, Japan	Japan Air Cleaning Association 6-7-5, Soto-Kanda, Chiyoda-ku, Tokyo 101
October 4-6	Third International Dental Congress on Modern Pain Control	Tokyo, Japan	Japan Convention Service, Inc Nippon Press Center 8F , 2-2 1, Uchisaiwai-cho, Chiyoda ku, Tokyo 100

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November 17-19	3rd JIM (Japan Institute of Metals) International Symposium	(undecided) Japan	The Japan Institute of Metals Aza Aoba, Aramaki, Sendai-shi, Miyagi 980
(undecided)	International Conference on Mass Spectroscopy	Hawaii, U.S.A.	Prof. T. Tsuchiya Basic Science Lecture Room Chiba Institute of Technology 1-17-2, Tsudanuma, Narashino Chiba 275
(undecided)	International Rehabilitation Medicine Association Fourth World Congress	Sydney, Australia	Prof G. G. Burniston Department of Rehabilitation Medicine, Prince Henry Hospital, Little Bay, N.S.W. 2036
(undecided)	Workshop on Marine Microbiology	Seoul, Korea	Korea Ocean Research and Development Institute P.O. Box 17, Yang-Jae, Seoul

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May 10-12	Royal Australian College of Physicians ASM	Sydney, Australia	RACP, 145 Macquarie Street, Sydney, NSW, 2000
May (tentative)	52nd ANZAAS Conference	Perth, Australia	Dr. G. Chandler University of Western Australia, Nedlands, W A 6009
August 1-7	International Association for Dental Research	Sydney, Australia	Mr. Scott Gotjamanos Department of Pathology, Perth Medical Centre, Verdon Street, Nedlands, W.A. 6009
August 17-24	Fourth International Congress of Plant Pathology	Melbourne, Australia	Mr. B. Price Victorian Plant Research Institute, Department of Agriculture, Victoria Swan Street, Burnley, Vic 3121
August 27-31	Twenty-fifth International Geographical Congress	Sydney, Australia	Australian Academy of Science, P O Box 783, Canberra City, A C T. 2601
August 28-September 2	29th International Congress of Physiology	Sydney, Australia	Australian Academy of Science, PO box 783, Canberra City, ACT 2601

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August 28-September 3	The 3rd International Mycological Congress (IMC 3)	Tokyo, Japan	Prof. K. Tsubaki, Institute of Biological Sciences, The University of Tsukuba Sakura-mura, Ibaraki Pref. 305
August 29-September 2	International Union of Physiological Sciences Congress	Sydney, Australia	Australian Academy of Science, P.O. Box 783, Canberra City, A.C.T. 2601
August (tentative)	International Solar Energy Congress	Perth, Australia	Mr. P. Driver, Honorary Secretary P.O. Box 123, Nedlands, W.A. 6009
October (tentative)	8th International Conference on Calcium Regulating Hormone	(Kobe), (tentative) Japan	Prof. T. Fujita, 3rd Division, Dept. of Medicine, School of Medicine, Kobe University 7-13, Kusunoki-cho, Ikuta-ku, Kobe 650
October 29-November 3	71st FDI Annual World Dental Congress (Fédération Dentaire Internationale)	Tokyo, Japan	Japan Dental Association (Japanese Association for Dental Science) 4-1-20, Kudan-kita, Chiyoda-ku, Tokyo 102
(undecided)	Thirteenth International Congress of Chemotherapy	Melbourne, Australia	Dr. B. Stratford St. Vincent's Hospital, 59 Victoria Parade, Fitzroy, Vic. 3065

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- A Guide to the Manuscript Records of Australian Science. 1966 127 pages. Price $4.50.

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